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1 or damaged, against degradation from ultraviolet radiation,
and including thin film means to reflect a substantial
portion of incident, solar, near-infrared radiation.
Optionally, and preferably, the electrochromic glazing
5 assembly is blue or green in transmission, as viewed from
the vehicle interior, so as to reduce glare from the sun and
to optimize visibility and a true-to-nature blue view of the
sky.

10 In a collision, the glass typically used as the
substrate in vehicular rearview mirrors poses potential
hazards to the driver or other vehicle occupants. Since
glass easily shatters into sharp, irregular fragments, there
is a high likelihood of facial or other injury, typically
lacerative in nature, in any collision. For this reason,
15 prior known interior and exterior vehicular rearview
mirrors, which typically consist of a single glass piece
coated with reflective material, are conventionally
protected by applying a tape or a plastisol-type plastic
adhesive to the back surface of the glass piece.
20 Accordingly, if impacted or broken in an accident, and
shattered, glass fragments are retained by the tape or
plastisol-type plastic adhesive.

More recently, however, a new generation of
electro-optical mirrors has emerged which are fabricated
25 using two pieces of glass separated by a gap or space which
contains an electro-optic medium allowing variation in the
light reflected by the assembly. For example, in liquid
crystal rearview mirrors, the space between the transparent
front and reflective coated rear glass pieces is filled with
30 a semi-viscous liquid crystal material. In
electrochemichromic or electrochromic mirrors, the gap or

1 space contains a liquid, thickened liquid, gel or semi-solid material.

5 In these types of electro-optic, laminated mirror assemblies, scatterproofing of the rear glass piece is relatively easy since tape or plastisol-type plastic adhesives can be applied to its rear surface behind the reflective coating in the conventionally known manner. However, scatterproofing the front piece of glass in such a laminated assembly is difficult since the material used to fill the space between the front and rear glass pieces is usually insufficiently viscous or adhering to retain fragments of the front glass should it shatter in a collision.

15 Another problem encountered with electro-optic rearview mirrors and windows or glazing assemblies is degradation due to exposure to ultraviolet radiation over the life of the mirror or glazing. Ultraviolet (UV) radiation from the sun which penetrates the earth's atmosphere has a wavelength in the range between 290 and 400 nanometers (nm) and can cause breakdown in the operational characteristics of the electro-optical medium including chain scission, cross-linking and stimulation of chemical changes in the chemicals used to formulate the electro-optical medium. This interferes with electronic conjugation in the aromatic conjugated materials typically used and thus the electro-optic activity of those materials is impaired. Moreover, the medium will often discolor taking on a yellowish tint visible in light reflected or passing therethrough and drastically affect the usefulness of the rearview mirror or window. Such degradation from UV solar radiation is particularly problematic in

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1 electro-optical automotive windows which are typically
exposed to the full solar radiation, often when the
electro-optical medium is in its colored state.

5 In order to overcome ultraviolet radiation
degradation in such electro-optic rearview mirrors and
glazings, it is possible to add UV radiation absorbing
materials to the electro-optic medium. However, such UV
absorbing additives, especially in higher concentrations and
with broad UV absorbance, themselves impart a yellowish tint
10 to the materials to which they are added. Such yellow tint
is also visible in light reflected or transmitted
therethrough. Yellow is aesthetically displeasing in many
applications, and is particularly displeasing when used in
rearview mirrors. Consumer acceptance of rearview mirrors
15 having a yellowish tint or cast in the reflected light has
been poor. Moreover, yellow mirrors are efficient
reflectors of headlamp glare which itself is yellow.
Consequently, prolonged exposure to sunlight and UV
radiation, or reducing UV degradation in electro-optic
20 mirrors with UV absorbing additives, can create negative
consumer reaction and acceptance. Likewise, a yellow tint
in, for example, an automotive sunroof is consumer
displeasing as it detracts from the consumer's appreciation
of, and natural view of, the blue sky.

25 Another objective in the use of rearview mirrors
is the matching of human sight sensitivity in various light
conditions during the use of such mirrors to the glare
sources and ambient lighting present. It is known that the
spectral sensitivity of the human eye depends on its light
30 adaptation. Thus, daylight and night driving conditions
create differing human eye sensitivities. Further, nearly

1 all night driving is affected by the reflection of light
from the headlights of the driver's own vehicle on the road.
The electro-optic mirror assemblies of this invention
should, therefore, optimally be constructed to correspond as
5 much as possible with the eye sensitivities in both day and
night driving conditions.

The electro-optic media commonly used in
electro-optic mirrors and windows are often constituted of
materials and chemicals of a potential toxic or otherwise
10 hazardous nature. Should the mirror glass break in an
accident, there is a possibility of automobile occupants
contacting the electro-optic media, either directly or by
contact with glass particles to which these potentially
hazardous media are still adhering. Such contact presents a
15 hazard to the occupants through toxic effects, and through
skin irritation such as to eyes and facial areas. The
anti-lacerative layers and laminate interlayers of this
invention offer a barrier that ensures that contact with
chemicals used within the mirror is minimized should the
20 glass shatter in an accident.

Yet another problem is unwanted misting or fogging
of the rearview mirror surface or the glazing surface when
the vehicle encounters high humidity conditions. For
example, in damp, cold conditions where the interior
25 passenger compartment of a vehicle has a highly humid
atmosphere, water droplets may tend to condense on the
rearview mirror surface or window surface thereby obscuring
vision in the mirror or through the window. Not only does
such condensation prevent effective use of the mirror or
30 window, but also requires frequent wiping by the vehicle
driver which distracts his attention from driving.

1 Vehicular windows provide a field of view so that
the driver can make safe driving decisions and allow
occupants to comfortably view the surroundings. Glass
vehicular sunroofs are luxury items that serve both
5 aesthetic and functional needs. A transparent sunroof is
primarily consumer-selected so that the occupants feel less
claustrophobic and more linked to the outside environment.
Sunroofs have a functional benefit in that, when opened,
they can greatly increase cabin ventilation and so
10 substitute somewhat for air-conditioning.

 As reviewed in the publication SMART WINDOWS FOR
AUTOMOBILES by Niall R. Lynam, SAE paper #900419, Society of
Automotive Engineers, International Congress and Exposition,
Detroit, Michigan, February 16 - March 2, 1990, the
15 disclosure of which is hereby incorporated by reference,
increases in the area of windows used in automobiles coupled
with down-sizing of vehicular air-conditioners and
environmental concerns associated with use of halocarbons in
air-conditioners, have led to an increased need to use solar
20 heat-load reducing glazing in vehicles. Since solar energy
(for solar mass 2) is, on the average, 3% ultraviolet (UV),
48% visible radiation, and 49% near-infrared (NIR)
radiation, nearly one-half of the solar energy can be
eliminated without any loss in visibility.

25 Solar-energy reducing glazing is already in use on
automobile windows and is based on two principles:
modification of the glass composition to increase the
infrared absorption; and deposition of single and multilayer
coatings to reflect or absorb infrared radiation. In a
30 vehicle, the glazing need not be concerned with heat
insulative properties such as are required for solar

1 efficient windows in buildings and homes. Building solar
windows allow as much of the solar spectrum as is possible
to transmit into the room but also trap this solar energy by
acting as a heat mirror for energy radiated from walls,
5 floors, furniture, etc.

With respect to a vehicle, heat built up when
parked or driven in sunny climates is the principal concern.
Thus, the solar glazing used in vehicles should, ideally,
reflect away all of the incident near-IR solar radiation
10 above around 800 nm since visible light is between about 400
and 800 nm. Even with such reflection, however, the
approximate 50% of solar energy contained in the UV/visible
spectral region, if transmitted, can contribute to heat
buildup within the vehicular cabin.

15 Chromogenic materials have been suggested for
providing electrically variable control over solar
transmission in automobile windows. SAE paper #900419
discloses a variety of possible designs and constructions,
among them being designs using liquid crystal or
20 electrochromic materials. Liquid crystal designs, and
particularly those that operate by scattering light rather
than by absorbing/reflecting light, however, yield only
moderate solar energy benefit when used in automobile
glazing. Electrochromic windows, because they do not
25 operate by a light scattering mechanism, are preferred for
use in variable transmission solar-efficient automobile
window glazing.

A wide variety of infrared attenuating means
including those that operate principally by reflecting
30 varying amounts of the near-IR region, or by absorption,
also have been disclosed in the prior art. Some have been

used in association with variable transmission liquid crystal panels. For example, U.S. 4,749,261 to McLaughlin et al. describes a liquid crystal material operable to modulate light transmitted through a panel such as a sunroof, window, or partition. The liquid crystal material selectively operates to transmit or to scatter light.

McLaughlin et al. describe an embodiment which includes an infrared light reflective material which may take the form of a stainless steel or tin oxide, optically transparent, infrared reflecting, and electrically conductive coating that preferentially reflects infrared light while allowing visible radiation to pass. McLaughlin et al., however, fail to explicitly distinguish to which portion of the infrared spectrum (i.e., near-IR between 800 nm and 2500 nm or IR above 2500 nm) their invention is directed, and fail to combine that revelation with an electrochromic medium. Other references have failed to distinguish the particular needs of vehicular variable transmission glazing from variable transmission glazing usable as building windows and the like.

Accordingly, a need is apparent for a laminate electro-optic vehicular rearview mirror and glazing assembly which can be effectively scatterproofed to retain glass fragments from both glass pieces in the assembly, protected against lacerative-type injuries, protected against ultraviolet radiation damage throughout its life, and protected against annoying fogging and misting of the interior cabin surface in high humidity conditions. In addition, there is a related need for electro-optic rearview mirror assemblies which provide reflected light of a commercially and consumer acceptable color or tint and which

1 match human sight sensitivity in both day and night
conditions to the glare sources and ambient lighting
present.

5 In addition, a further need is apparent for a
combination near-infrared attenuating/electrochromic window
which maximizes solar attenuation performance while allowing
maximum variability of visible light. There is also a
related need for a vehicular window which combines an
10 electrochromic medium which attenuates visible light by
absorbance and/or reflection with an efficient near-infrared
reflector and an ultraviolet reducing means. Further, there
is a related need for a solar attenuating window which can
be effectively scatterproofed to retain glass fragments from
the glass pieces in the window, protected against
15 lacerative-type injuries, protected against leakage of
chemicals, protected against ultraviolet radiation damage
throughout its life, and protected against annoying fogging
and misting of its surface in high humidity conditions.

SUMMARY OF THE INVENTION

20 The present invention overcomes the above problems
by providing a laminate electro-optic vehicular rearview
mirror which is protected against scattering of glass or
other mirror element fragments if broken or damaged in a
collision while reducing the risk of laceration from contact
25 with the front glass or other element. In addition, the
assembly is protected against degradation by ultraviolet
radiation. The ultraviolet radiation reduction may be
incorporated together with the scatterproofing,
anti-lacerative protection. Further, the assembly may
30 incorporate anti-fogging/anti-misting materials which

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1 prevent or reduce condensation and fogging in high humidity conditions.

5 In one form, the invention is an anti-lacerative, scatter protected, laminate, electro-optic rearview mirror assembly including first and second spaced optically transparent elements mounted in a mirror case. The elements each have front and rear surfaces defining a space between the rear surface of the first element and the front surface of the second element. An electro-optic medium is included
10 in the space and has a light transmittance variable upon application of an electric field. Means are provided for applying an electric field to the electro-optic medium to cause variation in the light transmittance thereof. A reflective coating is included on one surface of the second
15 element and is adapted to reflect light incident thereon through the first element and the electro-optic medium. A layer of optically transparent, tear/perforation resistant material is adhered to the front surface of the first element for retaining and preventing scattering of fragments from that element in the event of damage or breakage and for
20 reducing risk of laceration from contact with the first element if damaged or broken.

The optical elements may be glass or plastic. The anti-lacerative, anti-scattering layer preferably is a sheet
25 of polymer material such as reticulated polyurethane. In order to reduce ultraviolet radiation transmitted into the assembly, the polymer may be a combination of polyvinylbutyral and polyester which has ultraviolet radiation reducing properties. Alternately, the
30 anti-lacerative layer may incorporate ultraviolet radiation absorbing, blocking or screening additives selected from the

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1 group including benzophenones, cinnamic acid derivatives,
esters of benzoic acids, salicylic acid, terephthalic and
isophthalic acids with resorcinol and phenols, pentamethyl
piperidine derivatives, salicylates, benzotriazoles,
5 cyanoacrylates, benzilidenes, malonates and oxalanilides
which may also be combined with nickel chelates and hindered
amines. These additives also stabilize the anti-lacerative
layer itself against ultraviolet degradation.

10 Another UV radiation reducing alternative is the
use of a clear, transparent UV transmission reducing coating
preferably applied to the front surface of the front glass
element followed by the anti-lacerative, scatterproofing
polymer layer.

15 It is also possible to incorporate a sheet
polarizer with the anti-lacerative layer, or apply a
dichroic, reflective filter material to the glass element
which provides wide band ultraviolet radiation reduction.
Examples of such filters include thin film stacks.

20 It is also possible to substitute a laminated
glass assembly for the front element, such assembly
including a pair of glass panels adhered to one another with
a sheet of polyvinylbutyral or sheet polarizer which have
ultraviolet radiation reducing qualities. An
anti-lacerative layer may be applied to the front surface of
25 the first of the two glass panels in such a laminate.

A second form of the invention is a reduced
ultraviolet radiation transmitting laminate electro-optic
rearview mirror assembly which also includes first and
second spaced optically transparent elements, an
30 electro-optic medium therebetween, means for applying an
electric field to the electro-optic medium and a reflective

1 element together. In addition, coatings or layers of UV
radiation reducing paint or lacquer or polymeric films may
be included on the interior, facing surfaces of the
laminate. Alternately, the panels of the laminate first
5 element assembly may be adhered via a moderate to low
modulus of elasticity adhesive layer which is preferably
poured between the panels, cured with ultraviolet radiation,
and which preferably includes an index of refraction similar
to that of the glass panels to reduce distortion.

10 It is also possible to incorporate UV radiation
reducing additives directly in the clear plastic when such
plastic is used to form the first optical element.
Alternately, UV reducing additives can be added to the
electro-optic medium for UV stabilization.

15 The present invention also provides a combination
near-infrared attenuating, electrochromic glazing assembly
which is protected against scattering of glass or fragments
if broken or damaged in a collision while reducing the risk
of laceration from contact. Further, protection is offered
20 against contact with the chemicals used in the
electro-optical medium should the assembly be damaged in an
accident. In addition, the window assembly is protected
against degradation by ultraviolet radiation. The
ultraviolet radiation reduction may be incorporated together
25 with the scatterproofing, anti-lacerative protection.
Further, the window assembly may incorporate
anti-fogging/anti-misting materials which prevent or reduce
condensation and fogging in high humidity conditions.

30 In one form, the invention is an anti-lacerative,
scatter protected, electrochromic glazing assembly including
first and second spaced optically transparent elements. The

elements each have inside and outside surfaces defining a space between the outside surface of the first element and the inside surface of the second element. An electrochromic medium is included in the space and has a light transmittance variable upon application of an electric field. Means are provided for applying an electric field to the electrochromic medium to cause variation in the light transmittance thereof. Near-infrared reflective means are located on at least one of the first and second elements for reducing the transmission of near-infrared radiation through said window assembly. The reflective means incorporate at least one semi-transparent, elemental, thin metal film which reflects at least about 30% of the solar energy for Air Mass 2 in the spectral region from 800 nanometers to 2500 nanometers. In a preferred embodiment, the thin metal film has a physical thickness of between about 80 angstroms and 300 angstroms and, preferably, of sheet electrical resistance of no greater than about 8 ohms/square.

The optical elements for the glazing assembly may be glass or plastic and may employ the same anti-lacerative, anti-scattering, absorbing/filtering, tinting and ultraviolet reducing means listed above for the optical elements of the electro-optic mirror. It is also possible to substitute a laminated glass assembly for the inside element or the outside element, such assembly including a pair of glass panels adhered to one another with an interlayer such as a sheet of plasticized polyvinylbutyral or equivalent which has ultraviolet radiation reducing qualities. An anti-lacerative layer may be applied to the inner surface of the first or innermost of the two glass panels where the first element is such a laminate.

1 In preferred forms, the near-infrared reflective
elemental thin film is sandwiched between optically
transparent layers consisting of metal oxide, nitride,
halide, or sulfide thin films. These thin films serve as an
5 undercoat to the thin metal film to enhance its bonding to
the substrate and as a visible light anti-reflection
overcoat to enhance visible light transmittivity. The
elemental thin metal film is preferably elemental silver or
a silver alloy such as with copper but with the silver being
10 the majority component. Gold, copper, or aluminum are
alternate choices.

Accordingly, the present invention recognizes and
applies novel protective concepts to laminate, electro-optic
vehicular rearview mirrors and glazings not previously
15 obtained. The invention solves three difficult problems
encountered in prior commercialization of laminate
electrochromic mirrors, namely, scatter protecting the front
glass element, reducing lifetime ultraviolet degradation
problems arising from the UV instability of the typical
20 electro-optical medium sealed between the glass elements,
and reducing fogging or misting caused by condensation in
high humidity conditions. Further, the invention enhances
the aesthetic appearance and customer acceptance of UV
stabilized, electro-optic rearview mirror assemblies which
25 would otherwise reflect light with a yellow tint by
absorbing light in the yellow/orange/red regions of the
visible spectrum to produce a commercially acceptable
silvery or silvery-blue reflection. Further, the invention
matches human sight sensitivity in both day and night
30 conditions for either inside or outside mirrors to the glare
sources and ambient lighting present by incorporating means

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1 causing light reflection in the blue region of the visible
spectrum and thus well-suited the mesopic human vision
range. In addition, these results are obtained in an
economical manner easily incorporated in existing rearview
5 mirror cases requiring no specialized supports or
surrounding apparatus in the vehicle.

The present invention also recognizes that maximum
solar attenuation performance can be obtained through the
combination of novel near-infrared attenuating concepts and
10 electrochromic concepts while maintaining maximum
variability of visible light. The glazing assembly
incorporating the near-infrared attenuating and
electrochromic means also incorporates the novel protective
concepts listed above which solve for glazings or windows
15 the similar problems encountered in prior commercialization
of laminate electrochromic mirrors, namely, scatter
protection, reduction of ultraviolet instability of the
typical electrochromic medium, and diminution of fogging or
misting problems. Further, the solutions suggested for
20 masking the yellow tint caused by ultraviolet reducers are
applicable to the window assembly.

These and other objects, advantages, purposes and
features of the invention will become more apparent from a
study of the following description taken in conjunction with
25 the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional side elevation of a scatter
protected, anti-lacerative, laminate, electro-optic rearview
mirror assembly of the present invention;

30 Fig. 2 is a sectional side elevation of a scatter
protected, anti-lacerative and ultraviolet radiation

1 protected, laminate, electro-optic rearview mirror assembly
of the present invention;

5 Fig. 3 is a graph showing percent transmission of
electromagnetic radiation of wavelengths between 230 and 500
nanometers through a two millimeter glass sheet coated with
indium tin oxide on one surface and having a sheet of
polyvinylbutyral/polyester composite adhered to its opposite
surface;

10 Fig. 4 is a graph of the percent transmission of
electromagnetic radiation of wavelengths between 230 and 500
nanometers through a two millimeter glass sheet coated only
on one surface with indium tin oxide;

15 Fig. 5 is a second embodiment of the scatter
protected, anti-lacerative and ultraviolet radiation
protected, laminate, electro-optic rearview mirror assembly
of the present invention;

20 Fig. 6 is a third embodiment of the scatter
protected, anti-lacerative and ultraviolet radiation
protected, laminate, electro-optic rearview mirror assembly
of the present invention;

25 Fig. 7 is a fourth embodiment of the scatter
protected, anti-lacerative and ultraviolet radiation
protected, laminate, electro-optic rearview mirror assembly
of the present invention;

30 Fig. 8 is an ultraviolet radiation protected,
laminate, electro-optic rearview mirror assembly of the
present invention;

Fig. 9 is a second embodiment of an ultraviolet
radiation protected, laminate, electro-optic rearview mirror
assembly of the present invention;

1 Fig. 10 is a scatter protected, anti-lacerative,
anti-fogging, laminate, electro-optic rearview mirror
assembly;

5 Fig. 11 is a graph showing percent transmission of
electromagnetic radiation through a one millimeter glass
sheet coated with indium tin oxide on one surface and a
coating of clear acrylic including CYASORBTM UV radiation
reducing compounds on its opposite surface;

10 Fig. 12 is a graph showing percent transmission of
electromagnetic radiation through a one millimeter glass
sheet coated with indium tin oxide on one surface and a
coating of clear acrylic on its opposite surface;

15 Fig. 13 is a graph showing percent transmission of
electromagnetic radiation through a one millimeter glass
sheet coated with indium tin oxide on one surface and clear
UV protecting lacquer on its opposite surface;

20 Fig. 14 is a fifth embodiment of the scatter
protected, anti-lacerative and ultraviolet radiation
protected, laminate, electro-optic rearview mirror assembly
of the present invention;

Fig. 15 is a third embodiment of an ultraviolet
radiation protected, laminate, electro-optic rearview mirror
assembly of the present invention;

25 Fig. 16 is a sixth embodiment of the scatter
protected, anti-lacerative, ultraviolet radiation protected,
laminate, electro-optic rearview mirror assembly of the
present invention;

30 Fig. 17 is a graph showing the solar spectrum in
the ultraviolet region incident at a desert location such as
Tucson, Arizona;

1 Figs. 18a and 18b are graphs showing the percent
light transmission of .063 inch thick, standard, clear, soda
lime glass in the ultraviolet and visible regions of the
spectrum, respectively;

5 Fig. 19 is a graph showing the solar radiation in
the ultraviolet region transmitted by 0.63 inch thick,
standard, clear, soda lime glass;

10 Fig. 20 is a graph showing the percent light
transmission of specific solutions of four cathodic
electrochemichromic compounds including methylviologen (MV),
ethylviologen (EV), benzylviologen (BV) and heptylviologen
(HV) in the ultraviolet region of the spectrum;

15 Fig. 21 is a graph showing the percent light
transmission of specific solutions of four anodic
electrochemichromic compounds including
dimethyldihydrophenazine (DMPA), diethyldihydrophenazine
(DEPA), tetramethylphenylenediamine (TMPD), and
tetratetramethylbenzidine (TMBZ) as well as thiafulvalene in
the ultraviolet region of the spectrum;

20 Figs. 22a and 22b are graphs showing the percent
light transmission of SOLEXTRA 7010TM blue tinted
specialized glass in the ultraviolet and visible regions of
the spectrum, respectively;

25 Figs. 23a and 23b are graphs showing the percent
light transmission of SUNGLASTM Blue blue tinted specialized
glass in the ultraviolet and visible regions of the
spectrum, respectively;

30 Fig. 24 is a graph showing the relative spectral
power of Standard Illuminant Sources A and C as well as the
main color bands of the visible spectrum;

1 Fig. 25 is a graph showing the dark/scotopic and
bright/photopic sensitivity of the human eye superimposed on
the spectral output of a tungsten lamp used as Standard
Illuminant A;

5 Figs. 26a and 26b are graphs showing the percent
light transmission of SUNGLASTM Green green tinted
specialized glass in the ultraviolet and visible regions of
the spectrum, respectively;

10 Figs. 27a and 27b are graphs showing the percent
light transmission of a pair of clear soda lime glass panels
laminated together by SAFLEXTM SR#11 polyvinylbutyral
sheeting in the ultraviolet and visible regions of the
spectrum, respectively;

15 Figs. 28a and 28b are graphs showing the percent
light transmission of BUTACITETM Cobalt Blue polymeric
interlayer sheeting laminated between two clear soda lime
glass panels in the ultraviolet and visible regions of the
spectrum, respectively;

20 Figs. 29a and 29b are graphs showing the percent
light transmission of a pair of clear soda lime glass panels
laminated by SAFLEXTM Blue Green 377300 polyvinylbutyral
sheeting in the ultraviolet and visible regions of the
spectrum, respectively;

25 Fig. 30 shows the percent light transmission of
conventional clear soda lime glass coated with UV absorbing
PC-60 lacquer;

30 Fig. 31 is a graph showing the percent light
transmission of clear soda lime glass having a UV absorbing
coating of ZLI-2456 lacquer;

1 Fig. 32 is a graph showing the percent light
transmission of clear soda lime glass coated with a sheet of
SCOTCHTINTTM SH2CLX clear polymeric film;

5 Fig. 33 is a graph showing the percent light
transmission of a 35 micron thickness coating of NORLAND NOA
65TM ultraviolet cured epoxy adhesive on clear soda lime
glass;

10 Fig. 34 is a graph showing the percent light
transmission of a 500 microns thick coating of a cured
mixture of 15% EPON 828TM, 35% HELOXY MK107TM and 50%
CAPCURE 3-800TM on clear soda lime glass;

15 Figs. 35a and 35b are graphs showing the percent
light transmission of a pair of clear soda lime glass panels
laminated together by BUTACITETM 14 NC-10 polyvinylbutyral
sheeting in the ultraviolet and visible regions of the
spectrum, respectively;

20 Fig. 36 is a graph which illustrates the solar
energy spectrum (for Air Mass 2) constituting the solar load
incident on an automobile;

25 Fig. 36a is a graph which illustrates the variance
of percent luminous transmission caused by varying the
thickness of a silver elemental thin film deposited onto a
soda lime glass substrate;

30 Fig. 36b is a graph which illustrates that the
thickness of a silver elemental thin film can be increased
to 300 angstroms while sustaining the percent luminous
transmission above 50%;

35 Fig. 37 is a sectional view of a first embodiment
of the scatter protected, anti-lacerative, ultraviolet
radiation protected, laminate, electrochromic, near-infrared
attenuated glazing assembly of the present invention;

1 Fig. 38 is a sectional view of a preferred thin film stack typically applied to a glass surface of one of the glass elements of the present invention to form a specialized near-infrared reflector;

5 Fig. 39 is an enlarged sectional view of the near-infrared reflector of the present invention applied to a surface of a glass element;

10 Fig. 40 is a sectional view of a second embodiment of the scatter protected, anti-lacerative, ultraviolet radiation protected, laminate, electrochromic, near-infrared attenuated glazing assembly of the present invention;

15 Fig. 41 is a graph which compares the near-infrared reflectance performance in the 800-2500 nm electromagnetic radiation region of the spectrum for a half-wave coating of ITO on glass, a full-wave coating of ITO on glass, and two different, commercially available heat mirror structures on glass;

20 Fig. 41A is a graph of the percent reflectance of near-infrared solar energy for Air Mass 2 in the 800 to 2500 nanometer spectral range for silver thin elemental films of thickness between about 60 and 400 angstroms on glass;

Fig. 41B is a graph similar to Fig. 41B but with the silver elemental thin film sandwiched between two 180 angstrom thick titanium dioxide layers on glass;

25 Fig. 42 is a sectional view of a third embodiment of the scatter protected, anti-lacerative, ultraviolet radiation protected, laminate, electrochromic, near-infrared attenuated glazing assembly of the present invention; and

30 Fig. 43 is a sectional view of perimetral coatings which can be applied to the scatter protected, anti-lacerative, ultraviolet radiation protected, laminate,

1 electrochromic, near-infrared attenuated glazing assemblies
of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

ELECTRO-OPTIC REARVIEW MIRROR DEVICES

5 Referring now to the drawings in greater detail,
Fig. 1 illustrates a laminate, electro-optic rearview mirror
assembly 10 having a front element 12 which is scatter and
anti-lacerative protected with a resinous, polymeric or
other coated or applied layer 14 on its first or front
10 surface 11. Element 12 is preferably formed from a
generally planar sheet of conventional soda lime window
glass as is second glass element 16 which is spaced slightly
rearwardly from front glass piece 12 to define a gap or
space 18 for receiving an electro-optic medium 20 as
15 explained below. As explained hereinafter, elements 12, 16
may also be resinous, polymeric sheets to further prevent
fragment scattering and lacerative injuries if broken and to
reduce weight. Space 18 is formed between the generally
parallel rear surface 13 of front glass element 12 and
20 forward facing surface 17 of rear glass element 16.
Preferably, each of the front and rear surfaces 13, 17 is
coated with a layer of indium tin oxide (ITO) which is
substantially transparent to incident visible light yet is
sufficiently electrically conductive to enable application
25 of an electric field or voltage across space 18 between ITO
layers 13a, 17a. Electrical energy is provided by wire
leads 22, 24 secured in conventional manner to the upper
portions of ITO coatings 13a, 17a as shown in Fig. 1.

30 The rear surface 25 of rear glass element 16 is
coated with a reflective layer 26 preferably of metallic
material such as aluminum, or a combination of silver and

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1 copper as is conventionally known. Such layer provides a
highly specular surface which reflects approximately 80-90%
of the light incident thereon through layer 14, front and
rear glass elements 12, 16 and electro-optic medium 20 in
5 space 18. In order to prevent scattering of glass fragments
from the rear glass element 16 in the event of breakage or
damage during a collision in the vehicle, a layer 28 of tape
or a plastisol-type plastic adhesive, typically about 0.1
millimeters thick, is applied to the rear surface of
10 reflective coating 26. Anti-scattering layer 28 may be
opaque, translucent or transparent since it is behind
reflective coating 26 and need not transmit or reflect any
light.

15 In order to confine and retain the electro-optic
medium in gap 18, a peripheral seal 29, formed from an epoxy
material which adheres well to the ITO coatings 13a, 17a on
glass surfaces 13, 17 is applied adjacent the periphery of
glass elements 12, 16. A suitable epoxy sealing material is
EPON 828TM from Shell Chemical Company of Houston, Texas
20 cured by polyamide based curing agents such as V-40TM from
Miller Stephenson Company of Danbury, Connecticut. The
epoxy is preferably silk screened onto the inner surface of
the front glass element 12 or the back glass element 16 or
onto both glass elements. The corresponding glass element
25 is then placed face to face with the still tacky epoxy.
Seal 29 is then fully cured, typically by placing the
assembly into an oven at 110° C. for three hours. Gap 18
can then be filled by a variety of means such as simple
injection of electro-optically active material using a
30 syringe or by vacuum backfilling using a technique well
established for manufacture of liquid crystal devices.

1 full transmittance of light and, hence, full reflectivity
from reflective layer 26.

5 Because the electro-optic media 20 such as those
described above are typically of relatively low viscosity
and have little or no capability of retaining or holding
solid elements thereto, the scatter and anti-lacerative
protection conventionally available through the use of tape
or plastisol layers such as those at 28 on rear glass
element 16 has been unavailable for use with the front glass
10 element 12 because transmission of light through the glass
element must be unimpeded. The present invention overcomes
that problem by providing scatterproofing, anti-lacerative
layer 14 which retains fragments should glass element 12 be
shattered. Layer 14 also provides enhanced anti-lacerative
15 protection since it remains intact upon collision, is tear
and perforation resistant and thus reduces or avoids
laceration injury to the skin of any person contacting the
shattered or broken mirror.

20 A specific example of a material found useful for
layer 14 is reticulated polyurethane having a thickness
within the range of about 0.01 to about 0.25 inches and
marketed under the trade name SECURIFLEXTM by Saint-Gobain
Vitragé of Paris, France. When used as layer 14,
SECURIFLEXTM has excellent adhesion to glass surface 11 for
25 retaining glass fragments during and after shattering in a
collision. It also has high deformation capacity to resist
tearing while continuing to form a protective screen which
protects the skin of any person impacting the mirror and
preventing contact with broken, jagged edges of the glass.
30 It also has excellent optical quality, clarity and
transparency so as not to detract from the rear vision

1 capability of the rearview mirror. Further, it is abrasion
and scratch resistant so that high quality clear images can
be obtained in the mirror throughout its life. It is also
relatively inert and resistant to environmental variation
5 such as high and low temperatures, high and low humidity
conditions.

Use of an anti-lacerative layer 14 also affords
another advantage. It is known that several electro-optic
mirror devices developed in recent years have generally poor
ultraviolet radiation stability. When exposed to prolonged
10 ultraviolet radiation from sunlight, such electro-optic
assemblies may suffer substantial degradation of their
electro-optic media resulting in poor electrical coloration
responsiveness including increased response time and/or
15 failure to properly bleach when electric voltage is switched
off. Permanent discoloration of the medium may also occur.
This can cause substantial vision problems. An example of
the ultraviolet region of the solar spectrum incident at a
desert location such as Tucson, Arizona is shown in Fig. 17.
20 Such solar spectrum must typically pass through a glass
front panel of an electro-optic rearview mirror assembly to
irradiate the electro-optic solution in an electro-optic
rearview mirror assembly such as that shown in Fig. 1 or the
other assemblies shown herein. Fig. 17 shows that there is
25 little or no incoming solar radiation below about 295 nm.
The light transmission of a 1.6 mm thick panel of standard,
clear, soda lime glass is shown in Figs. 18a and 18b while
the solar energy spectrum transmitted into any electro-optic
medium behind such a front glass piece is the combination of
30 the graphs in Figs. 17 and 18 as shown in Fig. 19. The
0.063 inch (1.6 mm) soda lime glass panel passes about 63%

1 of the incoming UV solar energy in the 250-350 nm region and
about 90% in the 350-400 nm region. Overall, a 1.6 mm soda
lime glass sheet passes about 83% of the incident solar
energy in the 250-400 nm region. Thus, a substantial
5 portion of the incoming solar UV radiation is unattenuated
by the glass front panel.

When such solar radiation passes into the
electro-optic medium therebehind it irradiates the
electro-optic species. Electrochromic (ECC) materials,
10 especially organic species, are particularly susceptible to
degradation by UV radiation. This is caused by their
absorption of UV radiation with consequent disruption of
electronic states. As shown in the graph of Fig. 20, the
cathodically coloring ECC species most commonly used in
15 prior art literature such as methylviologen (MV),
ethylviologen (EV), benzylviologen (BV), and heptylviologen
(HV), have an absorption peak below 295 nm and, thus, are
largely nonabsorbing to the solar UV radiation transmitted
into an ECC cell. However, as shown in Fig. 21, anodic
20 compounds, such as dimethyldihydrophenazine (DMPA),
diethyldihydrophenazine (DEPA), tetramethylphenylenediamine
(TMPD), and tetratetramethylbenzidine (TMBZ) as well as
thiafulvalene have substantial UV radiation absorbance in
the 250-400 nm region. For example, DMPA in 0.0002M
25 solution in acetonitrile (AN) and in a 1 mm pathlength
quartz cell absorbs about 22% of the UV solar energy
spectrum in the 250-350 nm region. Therefore, it is
desirable to shield the ECC compounds from UV irradiation in
this region. Also, because some absorption continues up to
30 about 400 nm or so, and since the solar energy transmitted
into the cell as shown in Fig. 19 is also substantial in the

1 350-400 nm region, it is beneficial to protect the ECC
compounds from irradiation in this region as well.

5 The present invention recognizes that use of
ultraviolet radiation absorbing, blocking or screening
materials, either incorporated in the anti-lacerative layer
or in layers in addition to such layer, will reduce
ultraviolet radiation impinging on the mirror assembly and
the electro-optic medium and significantly prolong its
lifetime.

10 It is also recognized that substantial reduction
in the amount of UV radiation transmitted into the
electro-optic medium of the assembly may be accomplished by
using specialized glasses, paints/lacquers, and laminate
interlayers, coatings and/or films while simultaneously and
15 synergistically protecting a vehicle driver against
laceration or injury due to scattering or breaking of glass
fragments should the protected mirror assembly be struck in
an accident.

20 As shown in Fig. 2, an enhanced, laminate,
electro-optic rearview mirror assembly 35 with increased
ultraviolet radiation resistance and stabilization is shown.
As with subsequent embodiments of the invention explained
below, assembly 35 is similar to the mirror assembly 10 of
Fig. 1 but includes a different scatter protecting,
25 anti-lacerative, UV radiation reducing layer 36 on the front
surface of glass element 12. Layer 36 is preferably of
two-ply construction comprising a laminate of
polyvinylbutyral and polyester commercially available from
E. I. duPont de Nemours and Company under Product No. duPont
30 BE1028D and also has the same qualities as described for
polyurethane layer 14. The outer ply or layer 40 is

1 abrasion resistant, weather resistant, polyester while the
inner ply or layer 38 is resilient, tear resistant
polyvinylbutyral. Composite layer 36 has a thickness
preferably between about 0.005 and 0.25 inches, and provides
5 a solution to two problems found during commercialization of
prior known laminate electro-optic, and especially
electrochromic mirrors, i.e., difficulty in scatter
protecting the front glass element 12 and protection against
degradation of the electro-optic or electrochromic media 20
10 in space 18 throughout the lifetime of the assembly due to
inherent ultraviolet radiation instability and sensitivity.

The polyester/polyvinylbutyral composite layer 36
is a particularly good filter for ultraviolet radiation as
shown in Figs. 3 and 4. Fig. 3 is a graph of the percent
15 transmission of electromagnetic radiation through a two
millimeter thick element of conventional soda lime window
glass coated with a layer of indium tin oxide (ITO) on one
surface and a layer of duPont BE1028D polyvinylbutyral/
polyester composite on the opposite surface. The graph
20 shows the transmission over the wavelength spectrum between
230 and 500 nanometers (nm) and illustrates that below about
350-360 nm, wavelength transmission is cut off or stopped.
Ultraviolet radiation which penetrates the earth's
atmosphere from the sun typically ranges in wavelength over
25 a wide band of between about 290 and 400 nanometers (nm).
In contrast, light sensitive to the human eye ranges from
about 400 nm to about 700 nm. Hence, the composite
polyvinylbutyral/polyester layer 36 substantially eliminates
ultraviolet radiation below about 350 nm while
30 simultaneously scatter protecting and protecting against
laceration when applied to the mirror glass surface.

1 Compare the graph in Fig. 3 to that in Fig. 4
which illustrates a two millimeter glass element coated only
on one surface with indium tin oxide and not including a
polyvinylbutyral/polyester layer. Such ITO coated glass
5 transmits light in the visible wavelength spectrum above
about 400 nanometers but also allows transmission of
ultraviolet wavelengths down to about 295 nm which is
substantially farther into the UV region than with the
coated glass having the two-ply composite layer 36 thereon
10 as shown in Fig. 3. Hence, reduction of UV radiation
intensity passing through front glass 12 of such laminate
mirrors as in assembly 35 substantially increases the useful
lifetime of the mirror assembly.

15 A specific example of an assembly such as that
shown at 35 comprising a laminate electrochromic mirror and
providing the anti-lacerative, anti-scatter, UV radiation
reducing advantages of the present invention was fabricated
consisting of two plates of ITO coated, conventional soda
lime window glass separated by a gap of 50 microns. The
20 space between the two glass elements was filled with an
electrochromic solution consisting of N,N,N',N'
tetramethyl-1,4-phenylenediamine 0.025M,
1,1'-diheptyl-4,4'-bipyridinium dibromide 0.025M and
tetrabutylammonium fluoroborate 0.5M dissolved in propylene
25 carbonate. The nonmirrored front glass piece was
anti-lacerative protected with a duPont BE1028D two-ply,
anti-lacerative layer consisting of an outer abrasion
resistant layer of polyester and an inner layer of
polyvinylbutyral as described above in connection with Fig.
30 2. Reflective coated, rear glass plate 16 was scatter
protected on its rear surface using conventional tape. The

1 assembly was shattered by dropping a one kg weight over a
distance of one meter to impinge on the front nonmirrored
glass element, the anti-lacerative layer retained glass
fragments from the front glass and remained unperforated
5 such that it would have provided anti-lacerative protection
if struck by a person in an accident. Moreover, when this
laminate electrochromic mirror assembly was placed under UV
lamps in a sunlight simulator, electrochromic activity and
general mirror performance was maintained for a period of
10 some five (5) times longer than that obtained using a
control sample which was similarly tested with UV radiation
but was not anti-laceratively protected with a
polyester/polyvinylbutyral layer.

15 Although the anti-scattering, anti-lacerative
layer 14 of assembly 10 in Fig. 1 provides some ultraviolet
radiation reduction protection, and is itself ultraviolet
radiation stable, the polyvinylbutyral/polyester composite
is preferred since the polyvinylbutyral ply or layer has
significantly higher UV radiation reduction capability as
20 well as inherent UV stability than does polyurethane.

Longer lifetimes for laminate electro-optic
rearview mirror assemblies can be achieved by using
ultraviolet radiation absorbing, blocking or screening
materials added to or incorporated with the anti-scatter,
25 anti-lacerative layers 14, 36 as shown in Figs. 1 and 2.
Most commercial polymers absorb ultraviolet radiation
because they possess chromophoric groups either as regular
constituents or as impurities. Only those chromophores
which absorb electromagnetic radiation of a wavelength below
30 about 400 nanometers are, therefore, effective screens
against UV radiation. Polycarbonate, polyester and aromatic

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1 polyurethanes contain such chromophores as a major part of
their structures. However, polyolefins contain only
relatively insignificant amounts of these chromophores as
impurities. Yet, these above materials do not absorb UV
5 radiation uniformly over the entire UV range. The
chromophores which do absorb UV radiation can be conjugated
structures, carbonyl groups, aromatic repeat units and
heterocyclic repeat units. In addition, if polymers are
used as UV screeners, they themselves must be stabilized
10 against UV radiation since UV absorption generates free
radicals which lead to chain scission and cross-linking and
creation of other structures in these polymers. Thus, UV
radiation itself degrades the polymer material which is
intended to provide a UV absorber, block or screen by making
15 the polymer brittle and even imparting color in the visible
region.

The addition of UV absorbing, blocking or
screening additives to polymers such as the polyurethane
and/or polyvinylbutyral/polyester composite layers 14, 36
20 makes these materials more efficient UV screeners and
preserves their properties over a longer period of time.
Such UV additives, known as stabilizers, are transparent in
the visible region and work to absorb UV radiation, quench
the free radicals which are generated in the polymer and
25 prevent oxidation reactions which lead to polymer
degradation. For example, UV stabilizing additives drawn
from benzophenones, cinnamic acid derivatives, esters of
benzoic acids, salicylic acid, terephthalic and isophthalic
acids with resorcinol and phenols, pentamethyl piperidine
30 derivatives, salicylates, benzotriazoles, cyanoacrylates,
benzilidenes, malonates and oxalanilides are effective to

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1 block UV radiation and stabilize the polymer layer when
impregnated in such layer, included in separate coatings in
addition to such layer or incorporated directly in front
element 12 such as when it is cast from plastic. Other
5 additives may be combined with the above materials such as
nickel chelates and/or hindered amines. The following table
shows several combinations of commercially available
polymers and UV additives which may be used:

	<u>Polymer</u>	<u>Stabilizer</u>
10	Polyolefins	2-hydroxy-4-octoxybenzophenones nickel chelates hindered amines
	Styrenics	hindered amines 2-hydroxyphenylbenzotriazole
	PVC	benzotriazoles benzophenones acrylonitriles
15	Unsaturated Polyesters	2-hydroxybenzotriazole benzophenone
	Polyurethanes	benzotriazole pentamethyl piperidine derivatives
	Polycarbonate	2-hydroxy-phenylbenzotriazole
20	Polyamides	tetramethyl piperidyl sebacate
	Acrylic	2-hydroxyphenylbenzotriazole

In many instances, two or more of such additives are
combined together for increased, synergistic effects in UV
radiation reduction and stabilization.

25 UV stabilizers/blockers/filters/absorbers are
incorporated directly into the polymer anti-lacerative
layer(s) 14, 36 in a variety of ways. For polyvinylbutyral,
UV blocking additives are compounded with the PVB resin.
Alternately, the UV blockers are dissolved in plasticizers
30 which are then used to plasticize the PVB. PVB can also be

1 dissolved in a suitable solvent, with UV stabilizers next
added to the PVB solution and a UV stabilized PVB film/sheet
can be cast from this solution. UV blockers can also be
5 incorporated into polyester either through compounding or by
solvent casting. Polyurethane anti-lacerative sheeting is a
thermoset usually formed from reaction of isocyanate and
polyols. Since both of these starting materials are
liquids, UV blockers/stabilizers/filters/absorbers can be
10 added to either the isocyanate component or the polyol
component or to both. Concentrations of the various
additives for combination with the various polymers are
conventionally known such as are disclosed in U.S. Patent
No. 4,657,796 to Musil et al.

15 As an alternative, UV blockers, filters or
screens, or absorbers may be coated directly onto the front
element 12, preferably on the first surface 11, regardless
of whether it is glass or plastic (see Fig. 9). A clear
transparent coating packed with UV blockers/filters/
20 absorbers may be cast, spun, dipped, brushed, painted or
sprayed onto glass surfaces through which UV radiation must
pass before reaching the electro-optically active medium. A
suitable solution can be made by dissolving a clear
thermoplastic acrylic, polystyrene, NAS (70% polystyrene;
30% acrylic copolymer), polycarbonate, TPX
25 (polymethylpentene), or SAN (styrene acrylonitrile
copolymer) in a suitable solvent such as acetone, ethyl
acetate, acetonitrile, tetrahydrofuran or any other common
volatile solvent. To this, UV blockers are added such as
CYASORBTM UV1084 or UV5411, available from American Cyanamid
30 of Stamford, Connecticut, or any suitable material drawn
from known UV blockers up to concentrations close to their

1 solubility limit. CYASORBTM UV5411 is a benzotriazole while
CYASORBTM UV1084 is an organo-nickel complex or nickel
chelate. The solution so constituted can then be cast,
5 spun, sprayed, brushed, painted or dipped onto, for
instance, the outer surface of front glass element 12
followed by application of anti-lacerative layer 14 or 36
either with or without UV reducing additives as described
above.

10 For example, a 2.5% weight/volume casting solution
was prepared by dissolving commercial acrylic sheeting in a
50:50 mixture of acetone and toluene. To 100 mls of this
acrylic solution, 1.6 g of CYASORBTM UV1084 and 1.89 g of
CYASORBTM UV5411 were added. When cast onto a piece of one
15 mm thick ITO coated glass in a thickness of about eight
microns, the acrylic was UV stabilized and yielded the
transmission spectrum shown in Fig. 11. Transmission
through such coated glass in the region from about 280 nm to
about 350 nm was markedly reduced compared to similar
20 transmission spectra generated when only a 2.5% non-UV
stabilized acrylic solution was cast onto ITO coated glass
(Fig. 12) or when no acrylic was cast and a spectrum of ITO
coated glass itself was generated (Fig. 4). In spite of low
UV transmission, the UV stabilized cast acrylic coating was
25 highly transparent in the visible portion of the
electromagnetic spectrum.

Alternatively, UV stabilizers/blockers/filters/
absorbers can be incorporated into the polysiloxane
solutions, such as Dow Corning ARCTM coatings, available
30 from Dow Corning Inc. of Midland, Michigan. These are
commonly available to impart a transparent anti-abrasion
coating onto optical plastics which can be used for front

1 element 12 to further reduce fragment scattering and
laceration-type injuries. Alternately, UV stabilizers/
absorbers/blockers/filters can be added to thermosetting
optical plastics such as CR-39TM (allyl diglycol carbonate)
5 or optical nylons or polysulfones. With thermosetting
materials such as CR-39TM optical plastic, available from
PPG Industries, Inc. of Pittsburgh, Pennsylvania, the UV
absorbing, blocking or screening additive is incorporated in
the initial plastic components and cast onto the front
10 surface of front element 12 prior to assembly followed by
suitable curing in the conventionally known manner.

If a UV absorbing/blocking/screening material such
as CR-39TM above is cast as a separate sheet, it may then be
mounted on and adhered to front surface 11 of a clear
15 plastic front element 12 with an adhesive bonding substance
such as VERSILOKTM acrylics available from Lord Corporation
of Erie, Pennsylvania. In such case a UV reducing additive
such as benzotriazoles or hindered amines can also be
incorporated directly in the adhesive bonding agent.
20 Alternately, the sheet may be press laminated to the surface
under increased pressure and modest heat.

As an alternative to adding the UV reducing
additive materials to the scatter preventing,
anti-lacerative layers 14, 36 or other polymers, or as
25 coatings in combination with such anti-lacerative layers, or
as coatings in combination with the addition of the above
mentioned types of additives to such layers, other materials
may be used to decrease the ultraviolet radiation passing
through the front element 12 to the interior of the mirror
30 assemblies as shown in Figs. 5-10.

1 In Fig. 5, where like numerals indicate like parts
to those described above, a laminate, electro-optic rearview
mirror assembly 45 has front glass 12 replaced with a
5 laminate glass assembly comprised of a front glass element
12a having parallel front and rear surfaces adhered to an
intermediate glass element 12b also having parallel surfaces
by an interlayer 12c of polyvinylbutyral (PVB). Layer 12c
is adhered to the rear surface of glass element 12a and the
10 front surface of glass element 12b by heat and pressure
lamination such as with the conventionally known autoclave
method or the like. Glass elements 12a, 12b may be
conventional soda lime window glass. The rear surface of
glass element 12b is coated with indium tin oxide layer 13
15 which is, in turn, sealed with the front ITO coated surface
of rear glass element 16 by seal 29 to provide the space 18.
A scatter preventing, anti-lacerative, ultraviolet radiation
reducing layer such as that shown above at 14 or 36 may be
adhered to the front surface of front glass element 12a by
20 suitable adhesives, heat, pressure or curing to provide the
additional advantages noted above. However, the laminate
glass assembly of assembly 45 inherently affords extra
safety advantages by contributing to the reduction of
ultraviolet radiation transmission into the assembly and
providing greater shatter resistant strength for the
25 assembly while providing scatter protection due to the use
of the PVB layer 12c together with the anti-lacerative
protection of layers 14 or 36.

30 With reference to Figs. 6 and 7, where like
numerals indicate like parts, it is also possible to
incorporate sheet polarizers in the mirror assembly to
further prevent ultraviolet radiation transmission into the

assembly. In Fig. 6, a laminate electro-optic rearview mirror assembly 50 includes a layer of light polarizing sheet material 52 applied to the front surface 11 of front glass element 12 prior to adherence of the anti-scatter, anti-lacerative layer 14 or 36 mentioned above. A suitable H-sheet polarizer material is that sold under Product No. HN-38 by Polaroid Corporation of Cambridge, Massachusetts. Such sheet polarizers act to block and screen out ultraviolet radiation below wavelengths of about 380 nm.

Alternately, a sheet polarizer material 57 like that above may be incorporated in the laminate electro-optic rearview mirror assembly 55 of Fig. 7 where it is laminated and adhered as an interlayer between the front and rear surfaces of intermediate and front glass elements 12b' and 12a' to provide a glass laminate assembly. That glass assembly is substituted for front glass element 12 just as assembly 45 of Fig. 5. As with assembly 45, mirror assembly 55 has increased mechanical strength due to the laminate construction of the front glass panel, may incorporate scatter preventing, anti-lacerative layers 14 or 36 on the front surface of the front glass element 12a' for safety purposes, and reduces UV radiation transmitted into the assembly due to the UV absorbing and blocking function of the sheet polarizer layer 57 and any layer 14 or 36 to increase the lifetime of the assembly.

In Fig. 8, where like numerals indicate like parts to those described above, mirror assembly 60 includes a front glass element 62 formed from one of several types of specialized glass rather than conventional soda lime window glass. For example, front glass element 62 may have a higher iron oxide content of within the range of about 0.2%

to 0.9% by weight thereby increasing the ultraviolet radiation absorption, blockage and/or screening effect. Similar improvement can be obtained using higher cerium oxide content of 0.2% to 0.9% by weight concentration.

Other specialized glasses which have high visible transmission but are strong absorbers in the ultraviolet electromagnetic region can be used including NOVIOLTM glasses as described in "Spectral-Transmissive Properties and Use of Eye-Protecting Glasses" by R. Stair in National Bureau of Standards Circular 471 (1948). A two millimeter thick sheet of NOVIOLTM 0 CG306 (National Bureau of Standards Circular, 471 (1948)) transmits only about 12% of the incident ultraviolet radiation at 380 nanometers in contrast to transmission of approximately 70% of the incident ultraviolet radiation at 360 nanometers with a conventional soda lime window glass sheet. This is true even when such NOVIOL glass is coated with indium tin oxide as an electrical conductor. Conventional soda lime glass begins to screen out significant amounts of ultraviolet radiation only below about 300 nm.

Other useful specialty glasses include UV-36TM glass available from Hoya Corporation of Tokyo, Japan having an average transition wavelength of about 360 nm such that it cuts off ultraviolet radiation below that wavelength. Transition wavelength is the wavelength at the midpoint of the transition interval where glass goes from being highly transmitting to visible radiation to being highly absorbing for UV radiation. Other glasses which can be used include L-1BTM also available from Hoya Corporation having an average transition wavelength of 420 nm. Other examples include CS0501, No. 0-51TM available from Corning Glass

1 Works, Corning, New York having a transmittance less than
 0.5% at 334 nm and lower at shorter wavelengths but being
 highly transmitting in the visible electromagnetic region
 and FG-62TM available from Ohara Optical Glass Manufacturing
 5 Company, Ltd. of Tokyo, Japan, having a UV cutoff just
 slightly below 400 nm. Such ultraviolet radiation reducing
 glasses may be used either with or without scatter
 preventing, anti-lacerative, UV reducing layers 14 or 36 or
 the UV reducing coatings mentioned above. When used,
 10 however, the scatter preventing, anti-lacerative layers have
 the added advantage of significantly strengthening such
 glass which, in many instances, are mechanically weaker than
 conventional window glass. In addition such speciality
 glasses may be used in the laminate assemblies substituted
 15 for front element 12 as described with Figs. 5 and 7.

As mentioned above, elements 12, 16 may also be
 cut or cast from clear plastic sheet material such as
 acrylic or polycarbonate and used in place of front element
 62 of Fig. 8. Additives such as benzotriazoles and
 20 benzophenones may be incorporated in the plastic to reduce
 UV radiation transmission. Other UV reducing layers or
 coatings as described herein, including polymer layers 14,
 36, may also be used in combination with the plastic
 elements.

25 As shown in Fig. 9, wide band, ultraviolet
 radiation, dielectric, dichroic or reflective filter
 materials may also be used in conjunction with the front
 glass or plastic elements 12 or 62. Suitable dichroic
 filter or reflective materials include thin film coatings 67
 30 which significantly reduce ultraviolet transmission. Thin
 film layers 67 can be applied to any glass or plastic

1 surface ahead of the UV vulnerable electro-optic mirror
medium 20 but preferably on front or first surface 11. A
suitable thin film coating is the ultraviolet wide band
dichroic filter available from Optical Coatings Laboratory,
5 Inc. of Santa Rosa, California. When applied to the rear
surface of front element 12 or 62 as shown in Fig. 9 in
solid lines, coatings 67 are interposed between the element
rear surface and ITO coating 13a. When applied to the front
surface 11, however, thin film coatings 67 are interposed
10 between the front surface and the scatter preventing,
anti-lacerative layer 14 or 36 as illustrated in phantom.
Thin film coatings 67 have a transmission of visible light
over 80% at 550 nm with a sharply lowered transmission of
about 5% at 400 nm at which level the thin films become
15 reflecting to UV radiation.

As a substitute for the thin film coatings 67,
ultraviolet radiation blocking paints or lacquers can be
applied to the element surfaces provided such paints or
lacquers are transparent to visible light. A suitable
20 material for layer 70 is a lacquer supplied as ZLI-2456
transparent UV protecting lacquer which is a solvent based
acrylic with added UV stabilizers manufactured by E. M.
Industries of Hawthorne, New York. Such lacquer
substantially reduces UV radiation transmitted into the
25 assembly and is preferably applied to front surface 11 of
element 12 to avoid dissolving in medium 20.

For example, the above UV protecting lacquer
ZLI-2456 was coated on a one mm thick sheet of ITO
conductive glass to a thickness of about 30 microns. The
30 transmission spectrum of such coated glass is shown in Fig.
3. It has a sharp transmission cutoff below about 400 nm

1 and greatly reduces UV radiation in the 290-400 nm region as
compared to that normally transmitted by ITO coated glass
(see Fig. 4).

5 Thin film coatings or UV reducing paint or lacquer
layers 67, 70 may be used with conventional soda lime window
glass as front glass element 12, or with specialized UV
radiation reducing or higher iron oxide containing glass, or
other UV reducing elements 62 such as the plastic elements
mentioned above.

10 As shown in Fig. 10, a further embodiment 75 of
the laminate electro-optic rearview mirror assembly is
illustrated including a scatter preventing, anti-lacerative
layer 77 similar to the polyvinylbutyral/polyester composite
15 layer 36 described above in connection with Fig. 2 but also
including silicone moieties chemically incorporated in the
anti-lacerative composite. Polymer layer 77 including the
silicone additive prevents condensation and/or beading up of
condensed water on the coated front surface 11 of front
20 mirror element 12, 62 in high humidity conditions thereby
providing an anti-fogging, anti-misting result. A material
found useful as anti-lacerative, anti-fogging layer 77 is
silicone impregnated polyurethane supplied under the trade
name CLARIFLEXTM by Saint-Gobain Vitrage of Paris, France.
25 UV reducing additives such as those described above in
connection with Fig. 2 may also be incorporated in the
anti-lacerative, anti-fogging layer to increase the lifetime
of the assembly. Alternately, front glass element 12, 62
may be fashioned from conventional soda lime glass, UV
30 reducing specialized glasses, or polymer plastics. It is
also possible to utilize thin film coatings or UV reducing
paints or lacquers 67, 70 on at least one surface of front

1 element 12, 62 when the anti-lacerative, anti-fogging layer
is incorporated.

It is also possible to incorporate UV radiation
reducing or absorbing stabilizers directly in the
5 electro-optic medium 20 injected or otherwise inserted in
space 18. Such absorbers may be dissolved directly in the
medium, e.g., an electrochemichromic liquid. The UV
absorbers are selected to be compatible with the ingredients
of the medium 20, such that they do not affect the
10 electrical performance and function of the medium or oxidize
or reduce in the assembly.

As an example, a laminate electrochemichromic
mirror was fabricated as described in the above example in
connection with Fig. 2 except that no anti-lacerative layer
15 was used over front glass element 12. In addition, UV
stabilizers CYASORBTM UV1084 and CYASORBTM UV5411 were added
to the electrochemichromic active solution prior to filling
into the gap 20 between front glass 12 and back glass 16.
Concentration for the UV1084 was 0.6% by volume and the
20 UV5411 was 0.6% by volume g/cc.

As shown in Fig. 14, where like numerals indicate
like parts to those described above, another embodiment 85
of the laminate, electro-optic rearview mirror assembly also
includes a laminate glass assembly substituted for the front
25 glass as is the case in embodiments 45 and 55 in Figs. 5 and
7 above. The front or first, laminate assembly 86 includes
a front or first glass panel 12d having parallel front and
rear surfaces adhered to an intermediate glass panel 12e
also having parallel surfaces by an interlayer 12c of
30 polyvinylbutyral (PVB) or another interlayer as described
below. As in the prior embodiments, layer 12c is adhered to

1 the rear surface of glass panel 12d and to the front surface
of glass panel 12e by heat and pressure lamination such as
with the conventionally known autoclave method or the like.
In embodiment 85, however, glass panel 12d is formed from a
5 blue tinted specialized glass which significantly reduces UV
radiation transmission while maintaining high visible light
transmission. The rear surface 13 of glass panel 12e is
coated with an indium tin oxide layer 13a which is, in turn,
sealed with the front ITO coated surface 17 of rear glass
10 element 16 by seal 29 to provide electro-optic media
receiving space 18 as in the above embodiments.

Preferably, the blue tinted specialized glass 12d
is formed from SOLEXTRA 7010TM blue tinted glass available
from Pittsburgh Plate Glass Industries, Pittsburgh,
15 Pennsylvania. Graphs illustrating the percent transmission
of both ultraviolet and visible light for a 2.3 mm thick
pane of SOLEXTRA 7010TM glass are shown in Figs. 22a and
22b. SOLEXTRA 7010TM glass is highly visibly transmitting
at the 2.3 mm thickness, i.e., 83% transmission overall
20 using a Standard Illuminant C and a photopic detector (Fig.
22b). Also, this glass appears light blue in transmission
and strongly absorbs UV radiation below about 340 nm (Fig.
22a). At this thickness, Solextra 7010TM passes only about
2% of the incident solar energy in the 250-350 nm range. In
25 the 350-400 nm region, it passes about 67% of the incident
solar energy.

Alternately, glass panel 12d may be formed from
SUNGLASTM Blue, a blue tinted glass from Ford Glass Co.,
Detroit, Michigan. The spectral transmission for a 3 mm
30 pane of SUNGLASTM Blue, a blue tinted glass is shown in
Figs. 23a and 23b. This glass is highly visibly

transmitting at this thickness, i.e., 72% transmission overall with Standard Illuminant C and a photopic detector (Fig. 23b), appears light blue in transmission and strongly absorbs ultraviolet radiation below about 330 nm (Fig. 23a). Such thickness of SUNGLASTM Blue, a blue tinted glass passes only about 11% of the incident solar energy in the 250-350 nm range and 67% of the incident solar energy in the 350-400 nm range.

The above specialized glasses may also be used for second glass panel 12e or both panels 12d and 12e. Whether or not to use such specialized glass in both panels 12d and 12e is dictated by the degree of UV radiation protection desired, and by the degree of attenuation allowable in visible transmission of light that is concurrent with use of even thicker panes or multiple panes of blue tinted or similar light filtering panels.

Mirror assembly 85 incorporating one or more blue glass panels provides a unique advantage. As described above, UV radiation stabilizers may be added to enhance the UV radiation stability of an electrochromichromic solution used in a rearview mirror assembly. Broad UV radiation stabilizers such as CYASORB 24TM from American Cyanamid Company of Wayne, New Jersey, UVINUL D-50TM from BASF Wyandotte Corporation, Parsippany, New Jersey, or TINUVIN 327TM from Ciba Geigy, Hawthorne, New York, impart a yellow color to electrochromic or electrochemichromic solutions or materials, especially when they are added in high concentrations where they are most effective in protecting UV vulnerable materials. Yellow is aesthetically displeasing in many applications and is particularly displeasing when used in rearview mirrors. Also, when

electrochromic solutions are exposed to prolonged dosages of high intensity UV radiation, such as occur during natural weathering in sunny climates, those solutions frequently turn a yellowish hue which is aesthetically displeasing to the consumer. It has been found that use of specialized blue glass, such as that described above, allows use of higher concentrations of broad UV radiation stabilizers in electrochromic solutions than otherwise would be consumer tolerable due to yellowing.

As an example of an electrochemichromic device constructed according to Fig. 14, an electrochemichromic solution was formed from 0.025M methylviologen perchlorate, 0.025M 5,10-dihydro-5,10-dimethylphenazine, 0.025M tetraethylammonium perchlorate and 12.5% wt/vol CYASORB 24TM UV radiation stabilizer, all dissolved in 2-acetylbutyrolactone. When filled in cavity 18 of embodiment 85 as shown in Fig. 14, cavity 18 having a 150 micron thickness and using 15 ohms/sq indium tin oxide (ITO) transparent coatings 13a, 17a and with glass panels 12d and 12e both fabricated of 1.6 mm standard, clear, soda lime glass laminated together with a commercially available, clear PVB interlayer 12c SAFLEXTM SR#11 from Monsanto Company of St. Louis, Missouri, at zero potential and with a silver mirror reflector such as reflective layer 26 behind the assembly, the light reflected off mirror embodiment 85 has a distinct yellow tint and measures about 80% reflectivity using Standard Illuminant A and a photopic detector. Because consumers in automobiles are accustomed and appreciative of "silvery" reflection such as is found on interior and exterior automotive mirrors of conventional design, the marked yellow tint makes use of high

1 concentrations of broad UV radiation absorbers commercially
disadvantageous. Yet, such high concentrations of UV
absorbers have the advantage of affording greater UV
protection and, therefore, prolong the commercial life of
5 electrochemichromic rearview mirror devices, particularly
when used on the outside of a vehicle.

However, when a 2.3 mm pane of SOLEXTRA 7010TM was
substituted as the first glass panel 12d, with all other
factors being the same for the example of embodiment 85 as
10 described above, the reflection as seen in the mirror
reflector was no longer yellow but had a color or tint
described as gun metal blue to neutral silvery. This is a
much more acceptable and commercially desirable reflective
color than the yellowish tint previously obtained. Because
15 SOLEXTRA 7010TM glass panel 12d naturally filters out yellow
light thereby absorbing undesirable yellow tint, the
integrated reflection at zero potential in this version of
the assembly is lower than that using clear glass, i.e.,
about 63% reflectivity using Standard Illuminant A and a
20 photopic detector. However, such transmission is still
sufficiently high to allow successful use in vehicles,
particularly as outside mirrors.

Yet another advantage is obtained using embodiment
85 and the specialized glass panels 12d or 12e therein.
25 Blue mirrors are particularly well-suited to night driving.
Fig. 24 illustrates the relative spectral power output
versus wavelength of a CIE Standard Illuminant A and for CIE
Standard Illuminant C. Illuminant A is a Planckian radiator
at 2856K and, thus, is similar to an automobile headlamp.
30 Illuminant C provides light similar to average daylight.
Also included on Fig. 24 are the wavelengths of light which

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1 form the main bands of color in the visible spectrum. By
day, rearview mirror illumination is natural daylight
(similar to Illuminant C). By night, however, mirror
illumination will be that of headlamp output (similar to
5 Illuminant A) superimposed upon nighttime ambient light
which is essentially spectrally unbiased. Vision from a
mirror is also dependent on the spectral sensitivity of the
driver's eye. The spectral sensitivity of the human eye
depends on its light adaptation. If bright adapted, vision
10 is photopic and the spectral sensitivity is as shown in Fig.
25. If dark adapted, however, vision is scotopic and
sensitivity shifts toward the blue. Between these two
extremes vision is mesopic. Almost all night driving is in
the mesopic range of adaptation because the reflection of
15 the driver's own headlights from the road provide sufficient
illumination to maintain the adaptation level above the
scotopic range even on a very dark, unlit road. Because a
headlamp emits efficiently in the yellow/orange/red region
of the visible spectrum, but relatively poorly in the blue
20 region as shown in Figs. 24 and 25, and because a driver's
eyes when driving at night are somewhat more sensitive to
blue light, mirrors which optimize reflectance in the blue
spectral region but minimize reflectance in the
yellow/orange/red region best match human eye sensitivity in
25 day and night conditions, are most efficient at reducing
headlamp glare and are desirable as both inside and outside
rearview mirrors. Therefore, embodiment 85, which includes
the specialized tinted glass panel or panels, is efficient
in absorbing or filtering out substantially more light in
30 the yellow/orange/red regions of the visible spectrum than
in other regions of the visible spectrum. It tends to mask

1 yellowness due to any inclusion of UV radiation absorbers,
or due to any degradation of the EC or ECC material itself,
efficiently absorbs headlamp glare, provides a pleasing,
attractive reflective color, and allows matching to visible
5 blue tinted colors on outside mirrors when one side of the
vehicle has an electro-optic mirror assembly for the driver
and the other has a conventional, blue tinted,
passenger-side mirror. In addition, the blue tinted
embodiment 85 of the present mirror assembly is more restful
10 on a user's eyes since any yellowness otherwise present in
an electro-optic mirror assembly incorporating UV radiation
stabilizers is a more efficient reflector of light from a
yellow headlight and, thus, would reflect more glare to a
user's eyes than a comparable blue tinted mirror. Also, a
15 commercially useful advantage of SOLEXTRA 7010TM and
SUNGLASTM Blue glass panels is that they are relatively
inexpensive, namely, generally about two to three times the
already low commodity cost of conventional, clear, soda lime
glass.

20 Alternately, SunBlueTM glass from Asahi Glass
Company, Tokyo, Japan, can be used for one or both panels
12d and 12e. SUNBLUETM is a blue tinted float glass
incorporating added iron content and has a visible light
transmission of 83% at a 3 mm thickness (per JIS-R-3106) and
25 a UV radiation cutoff below about 330 nm.

Also, SUNGLASTM Green from Ford Glass, Detroit,
Michigan, a green tinted glass, could be used for either or
both of glass elements 12d and 12e in embodiment 85. As
shown in Fig. 26b, such glass, in a 3 mm thickness, is
30 highly light transmitting in the visible spectrum, i.e., 82%
transmission overall with Standard Illuminant C and a

photopic detector. It is also slightly green tinted and cuts off UV radiation transmission below about 330 nm as shown in Fig. 26a. This glass in such thickness transmits only about 6% of the incident solar energy in the 250-350 nm region, and about 60% in the 350-400 nm region.

A preferred material for the interlayer 12c of embodiment 85 is commercially available polyvinylbutyral (PVB) sheeting such as SAFLEXTM SR#11 PVB mentioned above. Such commercially available PVB sheeting is commonly used in automotive and architectural products and is formed by combining PVB resin with added UV absorbers, as described earlier. Such commercially available polyvinylbutyral (PVB) sheeting is heavily plasticized with at least about 19 parts of plasticizer per 100 parts of polyvinylbutyral resin using plasticizers such as triethyleneglycol dihexoate, triethyleneglycol di-2-ethyl butyrate, tetraethyleneglycol di-n-heptanoate, di-n-hexyl adipate, butyl benzyl phthalate, and dibutyl sebacate. Figs. 27a and 27b illustrate the ultraviolet and visible spectral transmission of a sheet of SAFLEXTM SR#11 PVB adhered between two 1.6 mm conventional, clear, soda lime glass panels. Such a laminated assembly, using clear glass and SAFLEXTM SR#11, transmits only about 8% of the incident solar energy in the 250-350 nm region and about 54% of such energy in the 350-400 nm region. When laminated, SAFLEXTM SR#11 sheeting is water clear in light transmission.

In general, various forms of SAFLEXTM polyvinylbutyral sheeting interlayers are acceptable for use in this invention as UV reducing interlayers. These include SAFLEX SRTM, SAFLEX TGTM and SAFLEX TLTM sheeting in thickness ranges between about 0.015 and 0.060 inch.

1 Thicker PVB interlayers provide better UV radiation
shielding but may cause visible distortion. Yet, thicker
sheeting is acceptable if due care is taken during
lamination. Generally, such SAFLEXTM sheeting is preferably
5 shipped and stored in a refrigerated or cold condition to
prevent the sheeting from sticking to itself while easing
handling and use. Other commercially available clear PVB
sheeting can be used. For instance, an architectural
composition such as BUTACITETM 14 NC-10 clear PVB sheeting
10 from E. I. duPont de Nemours and Company of Wilmington,
Delaware is a suitable choice. BUTACITETM is plasticized
polyvinylbutyral which is plasticized with
tetraethyleneglycol di-n-heptanoate, with a plasticizer
content (parts/100 parts resin) of about 38.5 or
15 thereabouts. When laminated between two panels of 2.3 mm
conventional, clear, soda lime glass as shown in Figs. 35a
and 35b, BUTACITETM 14 NC-10 clear PVB sheeting transmits
less than 0.1% of the incident solar energy in the 250-350
nm region and only about 25% in the 350-400 nm region.
20 Alternatively, BUTACITETM 140 NC-10, an automotive
composition or BUTACITETM 14 UV clear, an architectural
composition PVB sheeting can be used.

Alternately, a blue or blue/green tinted
interlayer 12c' may be substituted to form embodiment 85' of
25 the mirror assembly as shown in Fig. 14. Preferably,
BUTACITETM Cobalt Blue 0547800 polymeric interlayer sheeting
available from E. I. duPont de Nemours and Company of
Wilmington, Delaware can be used. The ultraviolet and
visible spectral transmission of BUTACITETM Cobalt Blue
30 sheeting, when laminated between two 2.3 mm standard, clear,
soda lime glass panels is shown in Figs. 28a and 28b. Such

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1 sheeting is a highly light transmitting polymeric material
having 78% overall visible light transmission with
Illuminant C and a photopic detector (Fig. 28b). It is blue
in tint and highly absorbing in the UV radiation range below
5 about 375 nm (Fig. 28a). It transmits only 0.01% of the
incident solar energy in the 250-350 nm region and about 24%
of such energy between 350 and 400 nm. By reason of its
blue tint, BUTACITETM Cobalt Blue sheeting also provides the
advantage of masking yellowness in the mirror to provide a
10 commercially acceptable silvery or silver-blue reflection
from assembly 85', while reducing headlamp glare and also
matching existing blue exterior rearview mirrors commonly
used in many vehicles.

15 BUTACITETM Cobalt Blue sheeting could be used
alone or in combination with one or both panels 12d, 12e of
embodiment 85 being specialized blue or green tinted glass.
Other suitable blue tinted polymeric sheeting interlayers
include BUTACITETM Automotive Blue Green 0377800, BUTACITETM
Automotive Green Blue 1107800 and BUTACITETM Light Blue
20 Green 0377300 also available from E. I. duPont in
Wilmington, Delaware. In addition, SAFLEXTM Blue Green
377300 available from Monsanto Company of St. Louis,
Missouri may be used. The ultraviolet and visible spectral
transmission of SAFLEXTM Blue Green 377300 sheeting is shown
25 in Figs. 29a and 29b. Alternately, SAFLEXTM Cool Blue
637600 or SAFLEXTM Solar Blue 755800 polymeric sheeting
could also be used.

30 With reference to Fig. 15, another embodiment 95
of the electro-optic rearview mirror assembly of the present
invention, where like numerals indicate like parts to those
described above, incorporates a single glass panel 97 having

1 parallel front and rear surfaces but formed from one of the
blue or green tinted specialized glasses described above in
connection with embodiments 85 and 85'. Thus, for example,
5 front glass element 97, which also includes a coating of
indium tin oxide 13a on its rear or inner surface 13, may be
formed from SOLEXTRA 7010TM blue tinted glass, SUNGLASTM
Blue glass, SUNBLUETM glass or SUNGLASTM Green glass. When
the blue tinted glasses are used, the resultant yellow
10 absorbing light advantages described above in connection
with embodiments 85 and 85' result in embodiment 95 as well.
These glasses are highly efficient in absorbing or filtering
out substantially more light in the yellow/orange/red
regions of the visible spectrum than in other regions of the
visible spectrum. With reference to the visible spectrum in
15 Fig. 24, such specialized glasses preferentially absorb
visible light with wavelengths generally higher than about
560 nm. In other respects, the embodiment 95 remains
substantially the same as embodiment 60 of the mirror
assembly. Optionally, panel 97 could be a panel of
20 specialized blue or green tinted safety glass that has been
tempered and/or toughened by conventional means which
include thermal tempering, contact tempering and chemical
tempering.

25 An alternate form 100 of the UV radiation reducing
embodiment 65 shown in Fig. 9 is illustrated in Fig. 16.
Mirror assembly 100, where like numerals indicate like parts
to those described above, includes a UV absorbing paint or
lacquer which is transparent to light in the visible
30 spectrum and may be applied as coatings 102, 104 on one or
both of the inwardly facing surfaces of glass elements 12a,
12b or 12d, 12e. These are the surfaces of the glass panels

1 which face one another and adhering interlayer 12c. A
 preferred UV absorbing lacquer is PC-60 from American Liquid
 Crystal Chemical Corporation of Kent, Ohio which is a
 solvent based urethane with added UV stabilizers. The
 5 ultraviolet spectral transmission of an approximately 32
 microns thick coating of PC-60 lacquer when applied to one
 surface of a 1.6 mm thick single panel of conventional,
 clear, soda lime glass is illustrated in Fig. 30. When
 applied as a coating, PC-60 is highly visibly transmitting,
 10 i.e., about 89% overall transmission with Illuminant C and a
 photopic detector, has a slight yellow tint, and absorbs
 sharply in the UV radiation region below about 390 nm.
 Between 250 and 350 nm, such a coating of PC-60 lacquer
 transmits essentially none of the solar energy incident in
 15 that region. For incident solar energy between 350 nm and
 400 nm, PC-60 lacquer transmits only about 5%. Overall,
 such a coating of PC-60 lacquer transmits only about 3% of
 the incoming solar energy in the 250-400 nm region.

20 An alternate UV absorbing lacquer is ZLI-2456
 mentioned above in layer 70 and useful to form embodiment
 100' (Fig. 16). A 12 microns thick coating of ZLI-2456
 transmits only about 2% of the incident solar energy in the
 250-350 nm region, and only about 9% of the solar energy
 normally incident between 350 and 400 nm. ZLI-2456 is
 25 slightly more yellowish in color and transmission than is
 PC-60 lacquer. Of course, UV absorbing paint/lacquer
 coatings such as those described above may be used with UV
 absorbing/filtering interlayers 12c or 12c' as described
 above, or when either of glass panels 12a, 12d or 12b, 12e
 30 are formed from blue or green tinted specialized glass as
 described above. Indeed, in a preferred form of embodiment

1 100, glass panel 12d will be formed from SOLEXTRA 7010TM or
SUNGLASTM Blue glass while the electro-optic media in space
18 will include UV absorbing additives as described above.
The ultraviolet spectral transmission of ZLI-2456 is shown
5 in Fig. 31.

As a specific example of mirror assembly 100 shown
in Fig. 16, an electrochromic solution was formulated
consisting of 0.02M methylviologen hexafluorophosphate and
0.02M 5,10-dihydro-5,10-dimethylphenazine dissolved in
10 2-acetylbutyrolactone. To this was added 12.5% wt/vol
CYASORB 24TM UV radiation absorber. This was filled into a
150 micron thick cavity between panels 16, 12b of ITO
transparent coated, 1.6 mm thick, conventional, clear, soda
lime glass. The ITO coating on each glass panel was 15
ohms/sq and had a visible transmission of 85%. A coating of
UV absorbing ZLI-2456 lacquer was spray coated on the front
facing surface 103 of rear glass panel 12b and on the rear
facing surface 101 of front glass panel 12a each to a
thickness of about 11 microns. Glass panels 12a, 12b were
20 then laminated by an interlayer 12c of SAFLEXTM SR#11 PVB
sheeting. When tested under mercury UV radiation lamps at a
temperature of about 80° C. for a period of approximately
two weeks, such a mirror assembly was found to be
exceptionally UV radiation stable. Integrated irradiation
25 in the 295-400 nm region within the UV radiation chamber
used to accelerate natural weathering was around 100W/m².
Initially electrochromic mirror devices with such UV
and anti-scatter protection had a reflection of
approximately 81% at zero potential which dimmed to a
30 reflectivity of approximately 8% when one volt potential was
applied across ITO coatings 13a, 17a which enclose the

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1 electrochemichromic solution. After over 336 hours in the
UV radiation chamber, the zero potential reflectivity
remained high at around 80% and the mirror continued to dim
to about 8% reflectivity when one volt was applied. The
5 appearance of the mirror remained essentially unchanged
after such prolonged exposure to high intensity ultraviolet
radiation. Also, when the safety performance of the mirror
assembly was tested by impacting it with a 0.9 kg steel ball
dropped from a height of 1 meter, the SAFLEXTM SR#11
10 laminating interlayer securely retained all shards of glass
such that they did not fly away and such that they remained
securely held to the laminate interlayer. Also, the
SAFLEXTM SR#11 laminate interlayer did not fracture nor tear
and was effective in ensuring that contact with chemicals
15 used within the electrochemichromic mirror assembly is
minimized should the mirror glass break in an accident.
Because of the high concentration (12.5% wt/vol) of broad UV
absorber CYASORB 24TM used in this embodiment, and because
of the slight yellow tint inherent to ZLI-2456 UV absorbing
20 lacquer, the reflection from this example of mirror assembly
100 had a somewhat yellow tint which is cosmetically
undesirable in some applications. However, when the front
glass panel 12a was replaced with a blue tinted glass panel
12d as described in embodiment 85, the benefits described
25 above were achieved. Specifically, when a 2.3 mm panel of
SOLEXTRA 7010TM glass was used as front glass panel 12d,
reflectance at zero potential remained close to its initial
64% in spite of over 336 hours of UV accelerated weathering
testing as mentioned above. Because of the use of blue
30 tinted glass, the reflector looked more silvery-blue and was
more consumer acceptable. Also, when dimmed by applying one

1 volt to the transparent coatings 13a, 17a, the mirror
continued to dim to its low reflection state of about 7%
reflectivity, even after prolonged exposure to the intense
UV radiation.

5 Also with reference to Fig. 16, an alternate
embodiment 110 substitutes different layers for
paint/lacquer layers 102, 104 preferably in the form of a
polymeric film such as clear SCOTCHTINTTM SH2CLX available
from 3M Corporation, St. Paul, Minnesota. Such SCOTCHTINTTM
10 film may be adhered as layers 112, 114 to one or both of the
inner facing surfaces of glass panels 12a, 12b or
specialized glass panels 12d, 12e as described above, said
placement on inner surfaces having the added advantage of
protecting the potentially scratchable polymeric film behind
15 glass panels 12a, 12d. Film layers 112, 114 (Fig. 16)
provide assembly 110 with similar UV reducing advantages
while maintaining strength and scatter preventing advantages
due to the laminate front assembly as in embodiments 100 and
100'. The ultraviolet spectral transmission of a single
20 layer film of SCOTCHTINTTM SH2CLX adhered to a sheet of 1.6
mm conventional, clear, soda lime glass is shown in Fig. 32.
SCOTCHTINTTM SH2CLX is a highly visibly transmitting film,
i.e., about 82% overall transmission using Illuminant C and
a photopic detector. It is also clear and absorbs sharply
25 and intensely in the UV region below about 380 nm.
Preferably, SCOTCHTINTTM SH2CLX film is used in a form
including a pressure sensitive adhesive applied to one
surface such that it may be easily adhered to the rear
facing surface of glass panel 12a or 12d and the front
30 facing surface of glass panel 12b or 12e. Likewise, such
polymeric film adds to the anti-scatter effect of the mirror

assembly 110 by retaining shards or splinters from glass panel 12a, 12d should it be broken upon impact. Also, by serving as a barrier film, they are effective in ensuring that contact with the chemicals used within the electro-optical mirror is minimized should the mirror glass break in an accident. Alternately, polymeric film such as SCOTCHTINTTM SH2CLX may be used in combination with clear or tinted UV reducing interlayers 12c or 12c' such as SAFLEXTM as described above.

As an alternative to using polymeric sheeting 112, 114 in mirror assembly embodiments 100, 100' or 110 as described above in Fig. 16, a UV curable, pourable adhesive can be used to retain the glass panels 12a, 12b or 12d, 12e together while simultaneously reducing UV transmission as embodiment 120 (Fig. 16). A suitable ultraviolet curing polyurethane adhesive modified so as to be UV curable is NORLAND NOA 65TM available from Norland Products, Inc., New Brunswick, New Jersey, which is water clear, highly transparent to visible light, includes a moderate modulus of elasticity when cured such that it is not overly brittle and does not fracture upon impact, and includes an index of refraction of 1.52 matched perfectly to that of soda lime glass (which has a refractive index of 1.52). NORLAND NOA 65 also adheres well to glass, is of relatively low viscosity (1,200 centipoise) such that it easily pours and spreads between two glass panels to allow lamination once cured. It also has a relatively low modulus of elasticity (20,000 psi). Its ability to be cured with UV radiation is well-suited to manufacturing processing. Fig. 33 illustrates the ultraviolet spectral transmission of a 35 microns thick coating of cured NORLAND NOA 65TM on a 1.6 mm

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1 conventional, clear, soda lime glass panel. Ultraviolet
radiation transmission is cut off below about 310 nm while
only about 19% of the incident solar energy in the 250-350
5 nm region is transmitted while about 62% of the incident
solar energy in the 350-400 nm region is transmitted.

Alternately, Norland NOA68, also a polyurethane
adhesive modified so as to be UV curable and also available
from Norland Products, Inc., can be used instead of NORLAND
NOA 65. NORLAND NOA 68TM has a refractive index of 1.54
10 matched closely with clear soda lime glass. It has a
modulus of 20,000 psi when cured and has an excellent
adhesion to glass. NORLAND NOA 61TM, which is a
polyurethane adhesive modified so as to be UV curable, can
also be used although, with a modulus when cured of 150,000
15 psi, it is somewhat more brittle. Alternately, DYMAX
LIGHT-WELD 478TM acrylic adhesive available from Dymax
Corporation, Torrington, Connecticut can be used. This is a
UV curing acrylic of Shore D hardness 65 that has a
refractive index of 1.507 which is very close to that of
20 soda lime glass when cured. Alternately, conventionally
known UV curing optical epoxies, preferably of low modulus
or with their modulus reduced through addition of reactive
diluent and reactive flexibilizers, as is commonly known,
can be used.

25 Should it be desired to further reduce the modulus
of elasticity of the cured adhesive, clear plasticizers or
clear low molecular weight epoxies can be added to the UV
curing adhesives so that they are less brittle after curing,
and such that they have even better lamination safety
30 performance. For example, cyclohexanedimethanol diglycidyl
ether such as HELOXY MK107TM from Wilmington Chemical

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1 Corporation of Wilmington, Delaware can also be added to
NORLAND NOA 61TM, NOA 65TM or NOA 68TM in quantities up to
30% wt/wt or more (i.e., % grams of MK107 added to grams of
NOA61, etc.) to plasticize them. HELOXY MK107TM has a
5 refractive index close to 1.48 which is also well-matched to
that of clear soda lime glass. At high concentration of
added MK107, the UV cured NOA61, NOA65 or NOA68 materials
are quite flexible and somewhat elastic such that they are
well-suited for use as anti-lacerative layers and as
10 laminate interlayers.

As an alternative to the UV curing adhesives
described above, thermally or catalytically cured adhesives
can also be used to retain glass panels 12a, 12b and 12d,
12e together while simultaneously acting as a UV radiation
15 reducing agent. As with the UV curing adhesives, the
thermally or catalytically cured adhesives are preferably
water clear, highly transparent to visible light, closely
matched to the index of refraction of glass, while being of
moderate modulus of elasticity when cured so as not to be
20 overly brittle nor to fracture upon impact and thus impair
retention of any glass fragments or shards. A suitable
system includes a modified epoxy adhesive formed from 15%
wt/wt EPON 828TM epoxy resin, mentioned above in embodiment
10, 35% wt/wt HELOXY MK107TM, and 50% wt/wt CAPCURE 3-800TM
25 mercaptan curing agent available from Diamond Shamrock
Chemicals Company, Morristown, New Jersey. These
ingredients are mixed together in a container and
subsequently spun in a centrifuge at approximately 4,500 rpm
for about ten minutes to remove entrained air. The
30 resultant viscous mixture is clear and is applied between
panels 12a, 12b or 12d, 12e. The resultant assembly so

1 formed is fired at about 110° C. for about one hour followed
by firing at 140° C. for a further hour. Such firing causes
the adhesive mixture to cure to an adhering but moderate
modulus of elasticity, somewhat flexible, optically clear
5 laminate. The ultraviolet transmission of a 500 microns
thick cured coating of this adhesive mixture, coated onto a
0.063 inch conventional, clear, soda lime glass panel is
shown in Fig. 34. Such material transmits about 35% of the
incident ultraviolet solar energy in the 250-350 nm region
10 thereby providing good inherent UV absorbing properties.

Also, it is possible to enhance the already good
inherent UV radiation absorbing properties of these UV,
thermally, or catalytically cured adhesives by adding any of
the UV absorbing materials such as UVINUL D-50TM, UVINUL
15 D-49TM, UVINUL 400TM, TINUVIN PTM, TINUVIN 327TM, TINUVIN
328TM, or CYASORB 24TM to the liquid adhesives prior to
their cure.

The UV, thermally, or catalytically cured
adhesives can also be optionally dyed so that they have a
slight bluish tint and provide the desirable properties for
20 the electro-optic mirror assemblies including specialized
blue tinted glass panels or blue tinted interlayers. For
example, taking the specific adhesive mixture of
EPON 828TM/HELOXY MK107TM/CAPCURE 3-800TM described above,
25 such mixture can be dyed blue using NEOZAPON BLUETM 807, a
phthalocyanine dye available from BASF Wyandotte
Corporation, Parsippany, New Jersey, added in about 0.5% to
1% by weight. When laminated between two 0.063 inch thick
panels of clear, conventional, soda lime glass, such a dyed
30 mixture, at 0.5% dye concentration, was highly visibly
transmitting (78% transmission using Illuminant C and a

1 photopic detector), was tinted blue, and was highly
absorbing in the UV region with only 30% transmission of
incident solar UV energy in the 250-350 nm region.

5 In any of the above mirror assembly embodiments,
and especially those utilizing one or more panels of clear
soda lime glass not already tinted blue or green as in
embodiments 85, 85', 100', 110 or 120, a blue,
electrochemically inert dye may be added to the
10 electrochromic or electrochemichromic solution itself to
provide the advantages of absorbing more light in the
yellow/orange/red region of the visible spectrum than in
other regions of the visible spectrum. Such a dyed assembly
will provide similar advantages to those including
specialized blue tinted glass or blue tinted interlayers.
15 For example, a suitable material such as NEOPEN 808TM, a
blue dye of the phthalocyanine type, is available from BASF
Wyandotte, Parsippany, New Jersey. Such material, dissolved
to a concentration of 0.1% wt/vol in propylene carbonate (a
common solvent used in electrochemichromic solutions), and
20 when placed in a 1 mm pathlength cell, transmits about 60%
of the visible spectrum (Standard Illuminant C and a
photopic detector), and transmits only about 9% of the
incoming solar UV energy in the 250-350 nm region.

ELECTROCHROMIC VEHICULAR GLAZING

25 Referring now to the window or glazing assembly
embodiment of the present invention, Fig. 37 illustrates a
laminate, electrochromic window/glazing assembly 200 having
a first optically transparent element 212 which is scatter
and anti-lacerative protected with a resinous, polymeric or
30 other coated or applied layer 214 on its inner surface 211.
Layer 214 is preferably formed from

1 tear-resistant, resilient material such as plasticized
polyvinylbutyral (PVB) sheeting having a preferred thickness
of from about 0.005 inches to about 0.060 inches. Element
212 is preferably formed from a sheet of conventional soda
5 lime window glass having a preferred thickness of from about
0.02 to about 0.25 inches as is second element 216, which is
spaced slightly outwardly from first element 212 to define a
gap or space 218 for receiving an electrochromic medium 220.
Also, element 216 is generally located closest to the
10 outside of the vehicle and, as such, is located closest to
the solar source of UV radiation. Generally, elements 212
and 216 are of compound, matched curvature. As explained
hereinafter, elements 212, 216 may also be optically clear
resinous, polymeric sheets to further prevent fragment
15 scattering and lacerative injuries if broken, to further
reduce UV transmission, and to reduce weight. Layer 214
also provides ultraviolet protection for the interior cabin
of the vehicle and protects against contact with whatever
chemicals are used in electrochromic medium 220 if element
20 212 should crack or break.

Space 218 is formed between the generally parallel
or tangentially parallel outer surface 213 of first glass
element 212 and inner facing surface 217 of second glass
element 216. Preferably, each of the inner and outer
25 surfaces 213, 217 is coated with a layer of indium tin oxide
(ITO) which is substantially transparent to incident visible
light yet is sufficiently electrically conductive to enable
application of an electric field or voltage across space 218
between ITO layers 213a, 217a. Layers 213a and 217a also
30 can be other transparent conductors such as doped tin oxide,
doped zinc oxide, and the like. Electrical energy is

1 provided by wire leads 22, 24 secured in conventional manner
to the peripheral portions of ITO coatings 213a, 217a as
shown in Fig. 37.

5 In order to confine and retain the electrochromic
medium in gap 218, a peripheral seal 229, formed from an
epoxy material which adheres well to the ITO coatings 213a,
217a on glass surfaces 213, 217 is applied adjacent the
periphery of glass elements 212, 216. A suitable epoxy
sealing material is EPON 828TM epoxy sealant from Shell
10 Chemical Company of Houston, Texas cured by polyamide based
curing agents such as V-40TM curing agent from Miller
Stephenson Company of Danbury, Connecticut. The epoxy is
preferably silk screened onto the inner surface of the first
glass element 212 or the second glass element 216 or onto
15 both glass elements. The corresponding glass element is
then placed face to face with the still tacky epoxy. Seal
229 is then fully cured, typically by placing the assembly
into an oven at 110° C. for three hours. Gap 218 can then
be filled by a variety of means such as simple injection of
20 electrochromically active material using a syringe. The
various electrochromic media proposed for use with the
electro-optic mirror are also suitable for use as the
electrochromic medium 220. In addition, the electrochromic
medium 220 can be one of the types described in the SAE
25 Paper #900419, the reference to which is incorporated
herein.

Fig. 37 depicts an embodiment of the present
invention where element 216 is a laminated composite formed
from a pair of glass panels 251, 252 like element 212. A
30 specialized near-infrared reflector 250 can be directly
deposited onto the inwardly facing surface 255 of panel 252.

1 In this arrangement, element 252 protects reflector 250 from
the outside environment and from abrasive damage as in car
washes and the like. Reflector 250 (shown enlarged in Fig.
38) preferably incorporates at least one semi-transparent
5 elemental metal thin film 256 of physical thickness in the
range of between about 80 angstroms to 300 angstroms and of
sheet electrical resistance of no greater than about 8
ohms/square. Elemental thin metal film 256 is
preferentially sandwiched between optically transparent thin
10 metal compound films 258a, 258b. Thin metal compound films
258a, 258b may be metal oxide, nitride, halide or sulfide
thin films. Among the possible thin metal compound films
are the following: zinc oxide, titanium oxide, vanadium
oxide, zirconium oxide, tungsten oxide, indium oxide,
15 bismuth oxide, magnesium fluoride, cerium oxide, indium/tin
oxide, tin oxide, zinc sulfide, silicon oxide and silicon
nitride. As shown in Fig. 39, in an alternative embodiment,
near infrared reflector 250 can be deposited onto a polymer
sheet or film 253, which polymer sheet or film itself is
20 capable of providing UV protection and shatter protection.

Layer 254 in Fig. 37 is an adhesive substance for
bonding panels 251 and 252 together. Layer 254 may
preferably be a specialized tear-resistant, resilient
interlayer of thickness 5 mils or greater such as BUTACITETM
25 14 NC-10 plasticized PVB sheeting from E.I. duPont de
Nemours and Company of Wilmington, Delaware which imparts UV
protection to electrochromic medium 220 and imparts scatter
protection directly to element 216, and indirectly to
element 212. Layer 254 can act to contain the
30 electrochromically active material contained in gap 218
should outer panel 252 and panel 251 shatter under impact.

1 Also, should tinting be desired, then tinted plasticized
polyvinylbutyral sheeting such as SAFLEX OPTICOLOR SYSTEMTM
interlayers from Monsanto Company of St. Louis, Missouri can
5 be used. Preferably, such tinting causes the assembly to
appear blue or green in transmission. This preserves the
natural color of the sky, spectrally filters yellow light
and, thus, protects from solar glare, thereby enabling use
of high concentrations of UV stabilizers and reducing UV
transmission through the assembly as a whole and into the
10 electrochromic medium in particular while simultaneously and
synergistically providing safety protection against contact
with broken glass and the chemicals used in the
electrochromic medium.

15 A second embodiment 202 of the window glazing
assembly invention is shown in Figure 40 where element 212
is the laminated composite formed from glass panels 251,
212. The specialized near-infrared reflector layer 250 is
sandwiched between elements 251 and 252 on the inwardly
facing surface of element 251. Thus, relative to the
20 vehicle outside, layer 250 is below the electrochromic
medium 220. Such a construction is less desirable than that
shown in Figure 37 because layer 250 is not in a position to
protect electrochromic medium 220 from the damaging effects
of solar near-infrared and ultraviolet radiation.

25 Figure 36 shows the solar energy spectrum Air Mass
2 that constitutes the solar load incident on an automobile.
Most of the solar intensity for Air Mass 2 is between 300
and 2100 nm. On the average, ultraviolet (UV) constitutes
3% of solar radiation (up to 400 nm), while visible light or
30 radiation is 48% (between 400 and 700 nm) and near-infrared
(NIR) is 49% (between 700 and 2100). If a perfect filter

1 could be designed to reject all solar NIR radiation, nearly
half of the solar energy could be rejected without any loss
of visibility.

5 As a specific illustration of the benefit
achievable through use of a specialized near infrared
reflector in combination with an electrochromic medium, UV,
luminous and solar transmission studies were performed on
both an electrochromic cell alone and on the combination of
commercially available heat mirror constructions with the
same electrochromic cell. The cell was formed by
sandwiching an electrochemichromic solution comprising;
0.035 M ethylviologen perchlorate
0.035 M 5,10-dihydro-5,10-dimethylphenazine
5% wt/vol UvinulTM 400 (2,4-dihydroxy-benzophenone)
15 dissolved in a solvent comprising 75% 3-hydroxypropionitrile
and 25% glutaronitrile. The cell gap was 135 microns. The
ITO transparent conductors sandwiching the
electrochemichromic medium were of half-wave (about 1500
angstroms) thickness and of sheet resistance 15 ohms/square
20 or thereabouts coated onto 0.043" thick soda lime glass
elements. Measurements were taken over four spectral
ranges, namely, ultraviolet (UV), visible, near-infrared
(NIR), and solar (Air Mass 2), of the attenuating
characteristics of this electrochromic cell construction,
25 both when the cell was bleached and when it was colored
under 1 volt applied potential. The results are summarized
in Table A.

TABLE A

Conventional Electrochemichromic Window
Half-Wave ITO Electrodes

	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Bleached	9%/5.5%	77%/10%	47%/17%	63%/13%
Colored (1.0 volt)	0.01%/5.3%	14%/6%	37%/16%	23%/10%

%T = Percent Transmission
%R = Percent Reflected

As can be seen from the data, this electrochemichromic window transmits about 63% of incident solar radiation when bleached and about 23% of incident solar radiation when fully colored under 1.0 volt applied potential.

Table B summarizes the results of similar measurements obtained when the electrochemichromic window cell of Table A was combined with a heat mirror glass commercially available from Cardinal Glass Inc. of Spring Green, Wisconsin in a manner similar to that shown in Figs. 37 and 38, but without any anti-lacerative layer.

TABLE B

Electrochemichromic Window Combined
with Cardinal Heat Mirror
Half-Wave ITO Electrodes

	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Bleached	7%/13%	64%/14%	24%/46%	46%/27%
Colored (1.0 volt)	0.1%/13%	12%/11%	18%/46%	14%/25%

The Cardinal Heat Mirror (see Figure 38) comprises a thin silver film 256 of thickness less than 300 angstroms incorporated in a multilayer thin film stack which includes

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1 a sandwich of zinc oxide thin film layers 258a, 258b on
glass panel 252. Note, from Table B, that combination of
the Cardinal Heat Mirror with the electrochemichromic window
allows preservation of a relatively high luminous visible
5 transmission of 64% (of benefit for automotive glazing such
as front, side, or rear windows where preservation of high
transmittance in the bleached state may be of safety
importance) while simultaneously significantly further
reducing the total solar load transmitted into the
10 automobile interior.

In the bleached state, use of the Cardinal Heat
Mirror achieves a reduction in solar transmittance from 63%
to 46% and, in the colored state, from 23% down to 14%.
Similar benefits can be obtained by combining alternate thin
15 film stacks to that utilized in the Cardinal Heat Mirror
with the electrochemichromic window. However, it is
important that the elemental metal layer 256 used therein
has a high carrier density and high charge mobility so that
its plasma edge rises early in the near-IR region thereby
20 reflecting the maximum near-IR solar radiation. Sheet
electrical resistance is preferably below about 8
ohms/square or thereabouts. Optionally, and given that
metal layer 256 is not contacting the electrochromic medium
and, as such, is electrically isolated therefrom, electric
25 current can be passed across metal layer 256 via wires or
other electrical connections secured to layer 256 from the
automobile electrical system for the purpose of heating and
defrosting the glazing assembly when so desired during
winter months and the like. The thin elemental metal layer
30 256 preferably has a physical thickness between about 80
angstroms and 300 angstroms. Below 80 angstroms, the

deposited coating is insufficiently continuous to yield good electrical conductivity and to achieve good near-IR reflectivity. Above 300 angstroms, the deposited thin elemental metal is overly opaque and overly luminous reflecting to be desirable for high transmittance applications, even when antireflected in a multilayer optical stack. These effects are illustrated in Figures 36A and 36B.

Figure 36A shows the % luminous transmission (with the source being Standard Illuminant A) as the thickness of a silver elemental metal film, deposited onto a soda lime glass substrate, increases in thickness from about 60 angstroms to about 400 angstroms. Note that % luminous transmission falls off rapidly and dramatically with increasing thickness of the silver film. However, when a construction such as is shown in Figure 38 or 39 is used with layer 258a being 180 angstroms thick film of titanium dioxide (refractive index 2.5), and layer 258b also being a 180 angstroms thick film of titanium dioxide (refractive index 2.5), and with these layers sandwiching a layer 256 of elemental silver, then, and as shown in Figure 36B, the thickness of the silver layer can be increased to 300 angstroms, or thereabouts, while sustaining % luminous transmission above 50%.

For many automotive glazing constructions, and especially for those involving compound curvature, it is desirable that the specialized near-infrared reflector be deposited onto a flexible element like layer 253 in Fig. 39 such as MYLARTM polyester film available from E.I. duPont of Wilmington, Delaware. Such polyester film is typically supplied in film thicknesses ranging from 0.001 to 0.050

inches or thereabouts. There are several advantages to use of a flexible polymer element for heat mirror coating. Being flexible and polymeric, it can be readily conformed under modest temperature and pressure, thus facilitating constructions where the rigid elements 212, 216, 251, 252, and the like are of compound curvature such as commonly found for automotive glazing. Also, the flexible polymer film can form a barrier affording protection against chemical leakage should the typically glass elements it contacts break or crack.

Such heat mirror coated flexible polymer film like 253 can be economically supplied coated on both surfaces with a conventional pressure-sensitive adhesive so that when sandwiched between glass as in the constructions contemplated in this invention, the flexible polymer film itself can afford a degree of safety protection to occupants in an accident. In addition, the polymer film itself can be a host for UV absorbers and so can supplement other UV attenuating means present in the construction as mentioned above regarding rearview mirrors (such as UV absorbers in solution in the electrochromic medium, such as glasses of increased iron oxide and/or cerium oxide content, use of a specialized UV absorbing glass for elements 212, 216, 251, 252, etc.). Further, the polymer film may be tinted to facilitate construction of tinted electrochromic windows.

An example of a near-infrared reflector forming a heat mirror which is deposited upon a flexible polymer film and is suitable to combine with an electrochromic window to achieve the objectives of this invention is HM-55 film from Southwall Corporation of Palo Alto, California. HM-55 includes a thin film coating of silver sandwiched between

indium oxide thin film layers, all in turn deposited onto a thin MylarTM flexible polymer film. Table C summarizes the results obtained when the electrochromic window cell of Table A was combined with a HM-55 heat mirror film by application to the outer glass surface.

TABLE C

Electrochromic Window Combined
with HM-55 Heat Mirror

Half-Wave ITO Electrodes

	UV 300-400 nm <u>T/R</u>	VISIBLE 400-800 nm <u>T/R</u>	NEAR-IR 800-2500 nm <u>T/R</u>	SOLAR 300-2500 nm <u>T/R</u>
Bleached	3.8%/43%	37%/46%	23%/77%	25%/58%
Colored (1.0 volt)	0%/43%	6%/44%	18%/77%	6%/58%

As indicated, the HM-55 film is relatively attenuating in the visible region so that this combination is best suited for applications such as an automotive sunroof where high bleached state transmittance is not necessary but where it is highly desirable to be darkly attenuating in the colored state and where exceptional solar performance in both the bleached and the colored states is desired. As Table C indicates, solar transmittance in the bleached state is only 25% and this decreases to a mere 6% when the electrochromic window is dimmed under 1.0 volt applied potential. Thus, the use of a thin elemental metal layer in combination with an electrochromic window (which itself is relatively solar transmitting in both the bleached and colored state) achieves exceptional solar performance for the combination. Note also that the UV transmission in the bleached state using HM-55 film is substantially reduced over that achieved with previously described designs, such

1 UV reduction being beneficial in avoiding degradation of
interior trim such as seats, carpets, etc. Note also the
low near-infrared solar transmittance through this assembly.
Such low UV and near-IR transmittance, even in the bleached
5 state, can have an important safety implication. The human
eye is not sensitive to radiation in the UV and near-IR
spectral region. Thus, it is important that UV and near-IR
transmission be minimized to avoid eye damage, and
particularly retinal damage, for consumers viewing the sky
10 and the sun through the electrochromic window assembly.

As an alternative to HM-55, HM-77, HM-66, HM-44,
and HM-33 heat mirror coatings on polyester film, all
available commercially from Southwall Corporation of Palo
Alto, California, can be used. HM-77 and HM-66 are low
15 reflectance heat mirrors most suited to automotive glazing
applications like front, side, and rear windows where high
luminous transparency is of benefit. HM-44 and HM-33 are
low transmittance heat mirrors most suited to automotive
glazing applications such as sunroofs where high
20 transparency is not a requirement. Also, all such heat
mirror multilayer stacks could be deposited onto tinted
polyester film to facilitate production of tinted
electrochromic window assemblies. Alternatively, the heat
mirror polyester films could be combined with tinted glass
25 such as GRAYLITETM, a dark gray tinted glass available from
PPG Industries Inc., Pittsburgh, Pennsylvania.

Alternatively, the specialized near-infrared
reflectors described above could be combined with
specialized UV-absorbing glasses such as AZURLITETM, a light
30 aqua (blue-green) tinted glass available from Pittsburgh
Plate Glass Industries, Pittsburgh, Pennsylvania, LOF

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EZ-KoolTM glass which is a green tinted glass of increased cerium oxide and iron oxide content, available from Libbey Owens Ford of Toledo, Ohio, or with equivalent specialized UV-absorbing glasses as described above in connection with the electrochromic mirrors. Such specialized UV-absorbing glasses have a higher iron oxide content of within the range of about 0.2% to 0.9% by weight and/or a higher cerium oxide content of 0.2% to 0.9% by weight. Even higher iron oxide and/or cerium oxide contents, such as 1% to 2% or more, can be contemplated, for applications such as sunroofs, etc., where the dark tinting that accompanies such high levels of iron oxide and/or cerium oxide may not be product objectionable. For specialized UV absorbing glasses that have a high iron oxide content, it is desirable to maximize UV absorption by maximizing the ferric (Fe III) ion content of the glass. Alternately, a specialized UV absorbing glass of titanium dioxide content greater than 0.2 weight percent or thereabouts can be used.

The exceptionally high near-IR reflectances, and consequent beneficial climate control when combined with an electrochromic window, attained by specialized near-infrared reflectors is not achieved by standard low-E coatings such as semiconducting oxides which are used in architectural climate control. This is illustrated in Table D and in the plots on the graph of Figure 41 which contrast the performance achieved using a multilayer stacks, such as the Cardinal Heat Mirror and the HM-55 film described above and incorporating an elemental metal thin film to the performance attained with a low-E coating such as half-wave (1500 angstroms) and full-wave (3000 angstroms) ITO.

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TABLE D

	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Half-Wave ITO	78%/13%	86%/10%	64%/17%	77%/13%
Full-Wave ITO	74%/16%	83%/12%	71%/17%	72%/14%
Cardinal Heat Mirror	53%/11%	83%/7%	42%/45%	65%/23%
HM-55	36%/44%	52%/40%	14%/81%	36%/57%

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Whereas the ITO coating merely reflects less than 20% of the near-infrared portion of the solar insolation in the 800-2500 nm region, the heat reflectors incorporating a thin elemental metal film significantly reflect near-infrared radiation in this region with the Cardinal Heat Mirror reflecting 45% solar near-infrared radiation and the HM-55 film reflecting 81% in this region. The reason for this good near-infrared reflectance performance is illustrated in Figure 41 which plots percent reflectance versus wavelength in the 800-2500 nm region for half-wave ITO, full-wave ITO, Cardinal Heat Mirror, and HM-55. The thin elemental metal film based near-infrared reflectors are seen to rise in reflectance earlier and sharper in the near-infrared region than what is achieved with the semiconducting ITO coatings. Thus, combination of thin elemental metal-based reflectors with electrochromic windows more closely approaches the ideal performance for automotive glazing which is independent control, via electrochromism, of visible light transmission while simultaneously achieving maximal (ideally 100%) reflectance of incoming near-infrared solar energy. In general, thin elemental metal-based reflectors useful to achieve the objectives of this invention reflect at least about 30% of Air Mass 2 near-infrared solar energy in the 800 nm to 2500 nm spectral range. The percent reflectance

of near-infrared solar energy for Air Mass 2 in the 800 nm to 2500 nm spectral range for silver thin elemental metal films ranging in thickness from about 60 angstroms to about 400 angstroms and deposited onto a glass substrate is plotted in Fig. 41A. As the graph shows, a silver film of at least about 60 angstroms, or thereabouts, thickness reflects at least about 37% of Air Mass 2 near-infrared solar energy in the 800 nm to 2500 nm spectral range. When a silver elemental thin film of thickness ranging from about 60 angstroms to 400 angstroms is sandwiched between two 180 angstroms titanium dioxide layers, with the resulting tri-layer stack itself deposited onto a glass substrate, the variation of percent reflectance of Air Mass 2 near-infrared solar energy in the 800 nm to 2500 nm spectral range versus thickness of the silver film is given in Fig. 41B. Note that the titanium dioxide layers have an anti-reflecting effect in this spectral region. For this stack design, a reflectivity in the 800-2500 nm spectral range for Air Mass 2 of at least about 30% is achieved for a silver film of at least about 75 angstroms or thereabouts.

Figure 42 illustrates another embodiment 206 of the invention, the performance of which is given in Table E.

TABLE E

UV Attenuating, Near-IR Reflecting,
Safety Protected Electrochromic Window

	UV 300-400 nm <u>%T/%R</u>	VISIBLE 400-800 nm <u>%T/%R</u>	NEAR-IR 800-2500 nm <u>%T/%R</u>	SOLAR 300-2500 nm <u>%T/%R</u>
Bleached	3.4%/10%	22%/26%	3.5%/29%	14%/27%
Colored (1.0 volt)	0%/10%	3.4%/26%	2.6%/29%	3%/29%

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Element 216 consists of panels 251, 252. Panel 252 is a blue-tinted, UV-absorbing specialized glass (3 mm thickness) available from Ford Glass Company, Detroit, Michigan, under the trademark SUNGLASTM BLUE. Layers 257a and 257b are blue-tinted plasticized polyvinylbutyral sheeting, each of sheet thickness 0.030", available from E.I. duPont de Nemours and Company of Wilmington, Delaware, under the trade name BUTACITETM Cobalt Blue B140 0547800. Layer 250 is a specialized near-infrared reflector available from Southwall Corporation of Palo Alto, California, under the trade name HM-55 film. Element 212 and panel 251 were coated on their respective surfaces 213 and 217 with a transparent conducting layer of full-wave indium tin oxide (ITO) of thickness approximately 3000 angstroms and of 7 ohms/square or thereabouts sheet resistance. The interpane gap 218 between elements 212 and 216 was about 135 microns in thickness. The electrochromic medium 220 was an electrochemichromic solution comprising:

- | | |
|-----------|--|
| 0.035 M | ethylviologen perchlorate |
| 0.035 M | 5,10-dihydro-5,10-dimethylphenazine |
| 5% wt/vol | UVINUL TM 400
(2,4-dihydroxy-benzophenone) |

dissolved in a solvent comprising 75% by volume 3-hydroxypropionitrile and 25% glutaronitrile. Coloration was achieved by applying 1 volt potential across the electrochromic medium 220. Antilacerative layer 214 is a two-layer composite comprising an inner tear-resistant sheet of plasticized polyvinylbutyral and an outer abrasion resistant layer of polyester, and is marketed under the trademark BE 1028 by E.I. duPont, Wilmington, Delaware.

1 Layer 214 can also include silicone moieties
chemically incorporated in the anti-lacerative composite to
prevent condensation and/or beading up of condensed water on
the coated front surface 211 of element 212, in high
5 humidity conditions thereby providing an anti-fogging,
anti-misting result. A material found useful as
anti-lacerative, anti-fogging layer is silicone impregnated
polyurethane supplied under the trade name CLARIFLEXTM by
Saint-Gobain Vitrage of Paris, France. UV reducing
10 additives such as those described above in connection with
Fig. 2 may also be incorporated in the anti-lacerative,
anti-fogging layer to increase the lifetime of the assembly.
Alternately, element 212 may be fashioned from conventional
soda lime glass, UV reducing specialized glasses, or polymer
15 plastics. It is also possible to utilize thin film coatings
or UV reducing paints or lacquers on at least one surface of
front element 212 when the anti-lacerative, anti-fogging
layer is incorporated. Likewise, it is possible to apply a
near-infrared reflector incorporating a thin elemental metal
20 film to front surface 211 of element 212.

The construction of Figure 42 is particularly
suited towards automotive sunroofs. As can be seen from
Table E, transmission into the vehicle interior is only 14%
of the solar Air Mass 2 spectrum, even in the bleached state
25 and this decreases to only 3% when the electrochromic medium
is colored. Note that visible transmission is 22% in the
bleached state (acceptable in an automotive sunroof where
the driver or vehicular occupant will be viewing the outside
bright sky through the sunroof) which decreases to only
30 about 3.4% visible transmission when the electrochromic
medium is colored under 1.0 volt applied potential.

1 (desirable in that the driver or vehicular occupant
perceives a significant visible attenuation when the
electrochromic sunroof dims and also benefits from reduced
solar glare). Further, and useful when both driving and
5 parked, the total solar load transmitted into the car
interior is drastically reduced, particularly when the
electrochromic medium 220 is colored. Hence, the car can be
parked for prolonged periods in a sunny climate without such
a sunroof contributing significantly to heat-buildup in the
10 car interior. Note also from Table E that UV transmission
through the complete assembly 206 is very small when the
device is bleached and is essentially eliminated when the
device is colored. Such UV reduction is beneficial in
avoiding degradation of interior trim such as seats and
15 carpets.

The appearance of assembly 206, when viewed from
the side of panel 252, is slightly but perceptively
metallic-like in appearance whereas, when viewed from the
side of layer 214, the appearance is more blue-like in
20 transmission. This is a benefit in that, since panel 252 is
on the exterior of the vehicle, assembly 206 has a more
metallic appearance while, to the vehicular occupant,
assembly 206 operates from a partial blue tint to a dark
blue tint. Thus, the driver and occupants simultaneously
25 benefit from a sense of privacy and from a sense of
user-control over the sunroof tint. When dimming or dimmed,
the change perceived from the outside of the vehicle is much
less than that experienced viewing from the car interior to
the outside sky. Thus, the outward appearance of the
30 vehicle remains fairly constant (of benefit to designers who
desire a style and color match of the sunroof or other

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1 glazing to the rest of the vehicle) while, simultaneously,
the driver or occupants perceive good value for their
investment in a controllable-tint glazing element. Also,
the blue tint of the assembly, particularly in its fully or
5 substantially bleached states, as seen in transmission from
the interior vehicular cabin to the outside sky is
particularly advantageous in that such blue tint selectively
and preferably absorbs glare from the sun which is
predominantly yellow in color while simultaneously
10 transmitting wavelengths in the blue and green region from
400 nm to 560 nm, and so preserving the blue, natural color
of the sky. Further, use of tinted means such as blue
tinted glass, blue tinted polymer layers and blue dyes in
the assembly allow use of increased concentrations of UV
15 stabilizers and absorbers while avoiding the consumer
undesirable yellow tint that usually accompanies such use of
high concentrations of UV stabilizers and absorbers. In
window assemblies, excellent UV stabilization is
particularly important given that the electrochromic device
20 will be exposed to intense UV solar radiation, typically
while in its colored state.

Also, for additional scatter protection and
safety, in any of the above disclosed mirror assembly
embodiments, any of the glass panels of the assemblies could
25 be formed from safety glass that has been tempered and/or
toughened by conventional means including thermal, contact
and chemical tempering. Also, such tempered, safety glass
can be blue or green tinted to provide the advantages
described above. In addition, layer 214 provides occupant
30 protection against injury due to scattered glass or
lacerative contact with broken shards and prevents immediate
occupant and interior trim contact with the solvents and

1 chemicals used in electrochromic medium 220. Likewise, and
particularly for applications such as a sunroof, sun visor,
or shade band where sun glare reduction, good shading
efficiency, and good thermal insulation performance is
5 desirable, at least one of elements 212, 216, 251 and 252
can be formed from architectural glass such as
SOLARBRONZETM, a bronze tinted glass; SOLARGRAYTM, a gray
tinted glass; GRAYLITETM, a dark gray tinted glass; and
SOLEXTM, a green tinted glass; all available from Pittsburgh
10 Plate Glass Industries of Pittsburgh, Pennsylvania;
SUNGLASTM Gray, a gray tinted glass; and SUNGLASTM bronze, a
bronze tinted glass; available from Ford Glass Company,
Detroit, Michigan; and with E-Z-EyeTM, a green tinted glass;
available from Libby Owens Ford of Toledo, Ohio. Further,
15 elements 212, 216, 251 and 252 can be coated with
low-emittance monolithic architectural coatings such as
SUNGATETM 100, a low emittance, high transmittance coating
available from Pittsburgh Plate Glass Industries of
Pittsburgh, Pennsylvania; and SUNGLASTM HR, a low emittance,
20 high transmittance coating available from Ford Glass
Company, Detroit, Michigan. Also, ECLIPSETM, a pyrolytic
Low-E coating available from Libby Owens Ford of Toledo,
Ohio can be used. Further, elements 212, 216, 251 and 252
can be coated with vacuum deposited architectural coatings
25 such as SOLARBANTM available from Pittsburgh Plate Glass
Industries of Pittsburgh, Pennsylvania, or can be coated
with KOOLOFTM, a solar control coating available from Libby
Owens Ford of Toledo, Ohio.

30 Further, perimetal coatings and darkened/color
matched seals, as described in copending patent application
serial no. 07/454,398, filed December 21, 1989, entitled

1 PERIMETER COATED, ELECTRO-OPTIC MIRROR, invented by Niall R.
Lynam, the disclosure of which is hereby incorporated by
reference herein, can be applied to window glazing
5 constructions such as shown in Figs. 37, 40 and 43. For
example, perimetral coatings 310 and 311 of Fig. 43, of a
conductive black frit or paint, can be applied around the
perimeter of surface layers 213a and 217a so as to hide from
view the seal 229 and the connection of electrical leads 22,
24 to layers 213a, 217a. A suitable material is ENGLEHARD
10 SC 6002 (# 6082), a platinum/palladium conductive ink
available from Englehard Corporation of Iselin, New Jersey.
Also, seal 229 can be color matched to any bezels, gaskets,
encapsulants, or vehicular body moldings used to fix the
electrochromic window assembly into a vehicle. For example,
15 carbon black, in a nonconducting form, could be added to
seal 229 in order to render it color matched to any black or
dark rubber or plastic encapsulation means used to secure
the electrochromic assembly into the vehicle. Alternately,
perimetral coatings 410, 420, as shown by the dashed lines on
20 Fig. 43, and formed from, for example, a frit material such
as DRAKENFELDTM black enamel 24-1729 available from
Drakenfeld Colors of Wilmington, Pennsylvania, can be used
to obscure from view the seal/electrical means used in the
assembly.

25 While several forms of the invention have been
shown and described, other forms will now be apparent to
those skilled in the art. Therefore, it will be understood
that the embodiments shown in the drawings and described
above are merely for illustrative purposes, and are not
30 intended to limit the scope of the invention which is
defined by the claims which follow.

Sub
all

FOOTNOTES